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Water Storage in the BIG HOLE

A Recommendation

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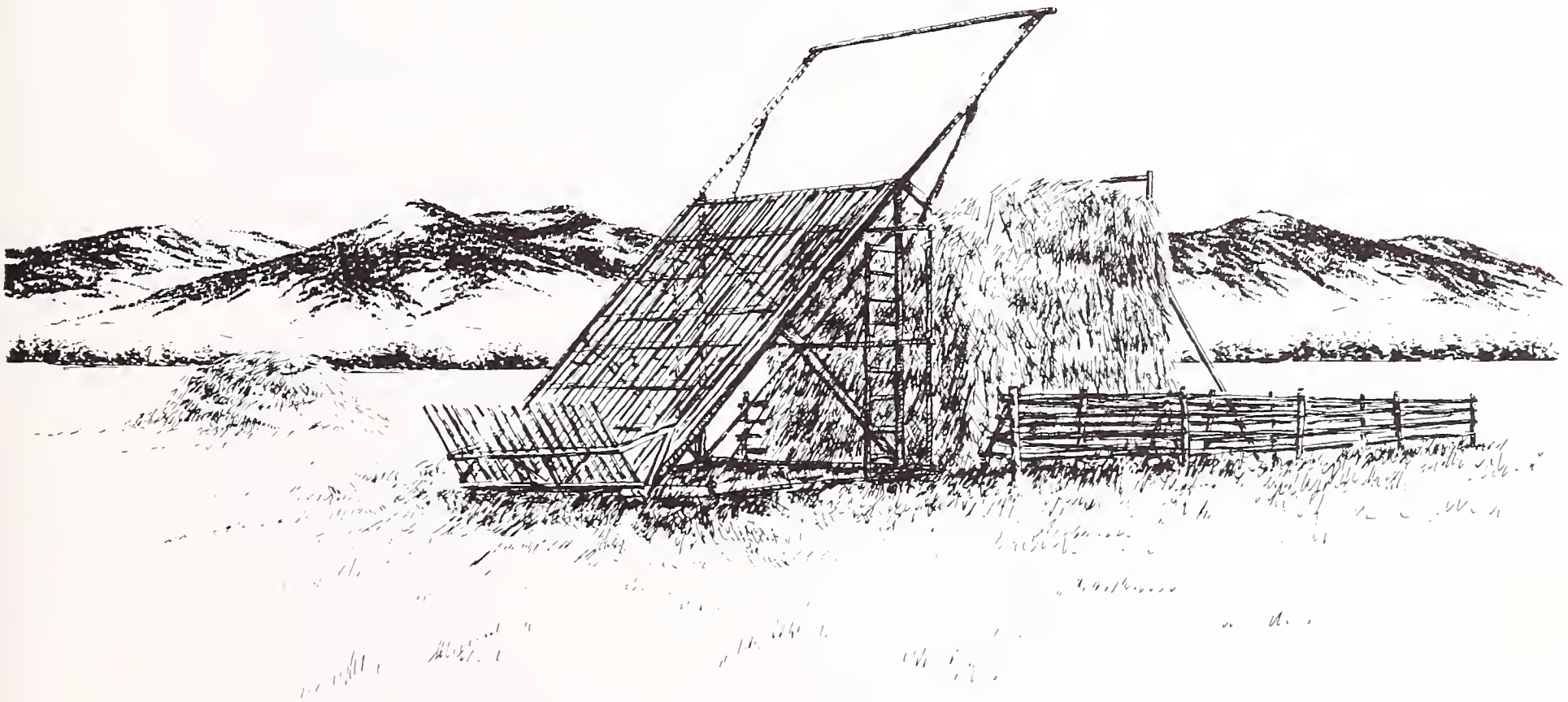
Water Storage in the BIG HOLE

A Recommendation



January 1981

Prepared by the Water Resources Division of the
Department of Natural Resources and Conservation
in response to H.B. 824

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SUMMARY

Water problems in the Big Hole basin have troubled irrigators since the turn of the century. Today the problems have become more complex. There just isn't enough water to satisfy the needs for it. Irrigators in the upper basin suffer water shortages annually. Some irrigators in the lower basin suffer shortages, and development of irrigable lands in both the lower and upper basins is halted by insufficient quantities of water. Dewatering threatens the quality of the fishery in the blue-ribbon reach of the Big Hole River.

Determined to address those problems, the Montana State Legislature passed HB 824 in 1979, directing the Montana Department of Natural Resources and Conservation to conduct a water demand survey in the Big Hole and Jefferson basins and to study tributary storage sites that have potential to provide water in sufficient amounts to relieve the shortages. This report, prepared by DNRC in response to HB 824, was prepared for the Forty-Seventh Legislature.

RECOMMENDATION

DNRC recommends construction of a dam on Pattengail Creek, a tributary of Wise River, which would provide water for instream needs, irrigation, and flood control. Construction would cost approximately $3.5 million, to be shared among those who use the water for such purposes as agriculture, instream use, and flood control. Approximately 10,000 acre-feet of water would be sold annually at a cost of $36/acre-foot. The first step toward building the dam is to obtain funding for detailed engineering and financial feasibility work. The likely source for this funding is the Renewable Resource Development Program. If the Water Development Program proposed by the Governor to the Forty-Seventh Legislature is passed, the feasibility and preliminary engineering plans would be carried out under this program.

WATER DEMANDS IN THE BIG HOLE BASIN

The current annual irrigation diversion requirement in the Big Hole basin is estimated at 381,888 acre-feet. About 24,787 acre-feet is diverted to the Beaverhead River basin annually. The instream flow requirement, determined by the Montana Department of Fish, Wildlife and Parks to maintain an ideal fish habitat, is 684,998 acre-feet per year. Municipal use, combining Jackson, Wisdom, Wise River, Divide, and Melrose with Butte Water Company, the major user, is currently 24,018 acre-feet per year. The total of all current uses is about 1,115,000 acre-feet per year, and the total average annual river discharge is about 1,132,372 acre-feet per year—more than enough to satisfy current uses. The difficulty is that the water is not available where or when it is needed. Both instream and irrigation shortages occur between mid-July and September.

Irrigators in the upper basin suffer water shortages almost annually in July and August when snowpack runoff has disappeared from the tributary streams. In a typical year, upper

basin irrigators receive only 30% of the water they need after July 15. In the lower basin, where the river has been classified as a blue-ribbon trout stream, there is enough water to meet both irrigation and instream needs in only three years of ten in August and only four years of ten in September. This is inadequate to support a true blue-ribbon fishery. Irrigation in the lower basin is mostly from ditches off the mainstem that serve several users. Typically, lower basin ditches higher on the river receive adequate supplies, but irrigators on the lower ditches have to curtail irrigation in about one year of three because there is inadequate water for diversion. Furthermore, there isn't enough water in the lower basin to irrigate additional irrigable lands. At present, there is little municipal use and it neither affects nor is affected by water shortages.

There are 133,854 acres now irrigated in the upper and lower basins. A total of 85,445 additional acres is potentially irrigable if cost and water availability are not considered. Of this, 45,405 acres may be economically feasible to irrigate if there is enough water to do so. There isn't.

There are no reported irrigation water shortages in the Jefferson River basin from Twin Bridges to Whitehall.

POTENTIAL SOLUTIONS TO WATER SHORTAGE PROBLEMS

Potential solutions to these shortages include mainstem storage, ground-water development, water conservation, water rental to alleviate instream shortages, and tributary storage.

The mainstem Reichle site would give a poor return on the investment, has been opposed by sportsman groups, and would not make water available to the upper basin where most of the irrigation shortages exist. It would also flood parts of the blue-ribbon stretch. DNRC does not recommend construction of a dam at this site.

Ground-water development—using water wells to provide irrigation water—could improve the shallow ground-water conditions that reduce crop productivity, make water available throughout the growing season, and relieve the water shortages in the basin. However, no one knows how much ground water the basin can yield. Also, there isn't enough electric power in the area to supply pumping requirements, and expansion of the power distribution system would be costly. Even when electricity is assumed to be available, costs for supplying ground water for irrigation are prohibitive at $55/acre-foot. For these reasons, ground-water development would not solve water shortage problems in the basin.

The continuous flood irrigation practiced in the upper basin is not efficient, but it is cost effective. It does not contribute to water shortages because the ground-water system is so saturated that most of the excess water applied to the land returns, rather quickly, overland to the water source. Therefore, conservation of water through more efficient irrigation practices in the upper basin would not relieve instream flow shortages or make significant amounts of additional water available for irrigation.

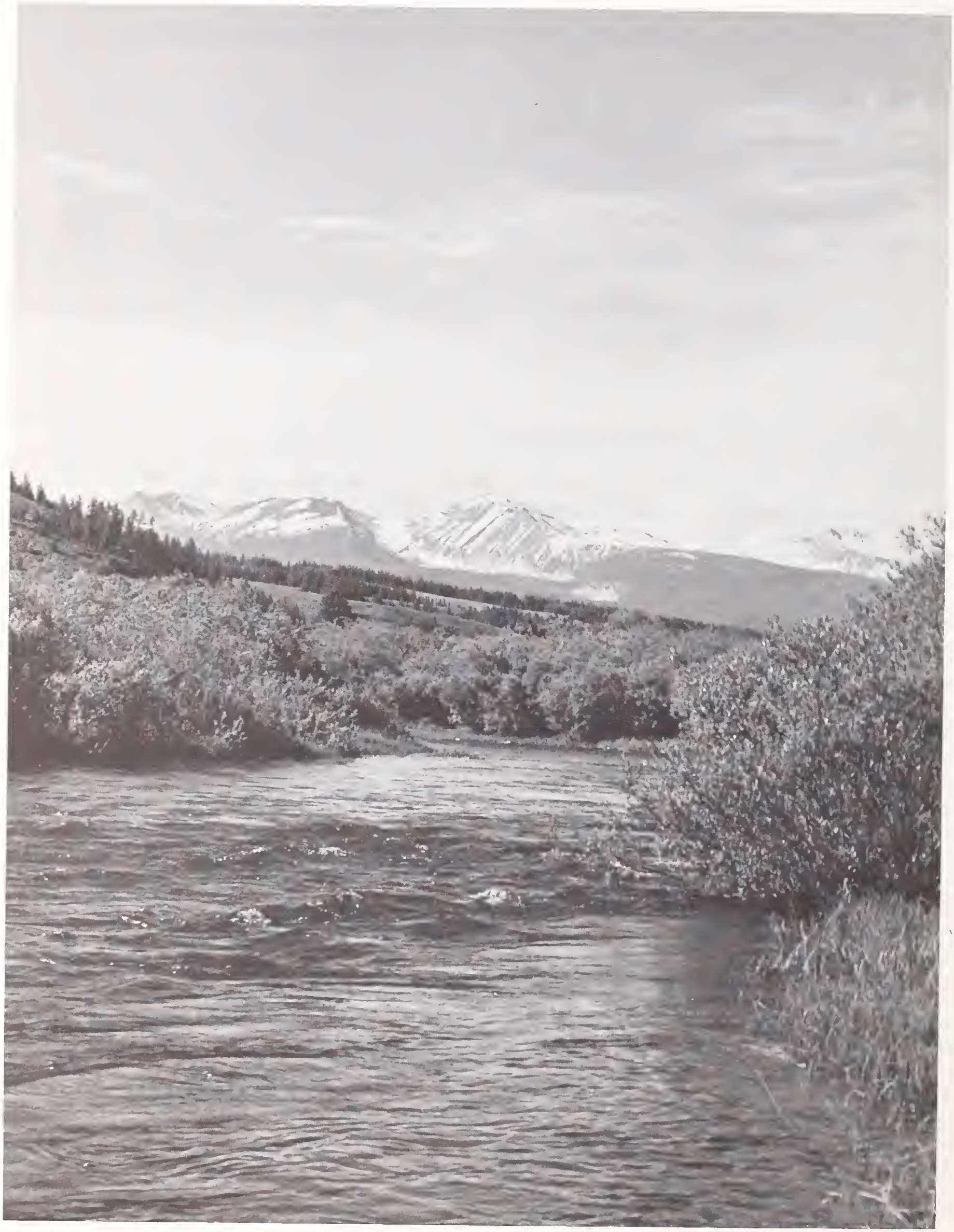
It would be possible, if some laws were changed, to rent water from irrigators to augment instream flows, renting the water only when needed at a price negotiated with a current user willing to agree to such an arrangement. Since an implementation plan for a water rental program has not been well developed at this time, DNRC does not recommend this approach in

the Big Hole. It is possible that this approach could solve water shortage problems in other areas.

Tributary storage is the most feasible solution to water shortage problems in this basin. DNRC studied twenty-two reservoir storage sites that had been culled from an original 120 potential sites, and further screened the twenty-two down to a final eight. A total reservoir storage of 173,000 acre-feet could be provided if all eight sites were constructed. Storage of more than 575,000 acre-feet of water would be needed to satisfy all diversion requirements and instream needs in every year in the upper basin alone. However, construction of a single carefully operated dam could reduce the shortages significantly. Because 70% of the irrigation needs in the upper basin occur along tributaries, tributary storage would be ideal to alleviate local irrigation shortages. In the lower basin, water from tributary storage would be added to mainstem flow where it would be used for both irrigation and instream needs.

The eight sites studied are on Francis Creek, Canyon Creek, Trail Creek, Johnson Creek, French Creek, Wise River, and Pattengail Creek. The sites on Francis Creek and Canyon Creek are geologically unsuitable for dam construction. Trail and Johnson creeks are located in the upper basin where there are irrigation shortages but no instream shortages. Because the water from these sites would be too expensive for irrigators alone to afford, the only financially feasible sites are those that serve the lower basin where instream interests can share the costs with agriculture. These sites are those on French Creek, Wise River, and Pattengail Creek. The site on Pattengail Creek is twice as large as that at French Creek (10,000 acre-foot firm annual yield versus 5,000) and the water is about one-half the cost ($36/acre-foot at Pattengail versus $60/acre-foot at French Creek); so, French Creek has been eliminated. The cost of water at the Pattengail site is approximately the same as at Wise River ($36/acre-foot for Pattengail and $30 for Wise River), but a proposal to build a dam at the Wise River site would cause substantial environmental concerns because the reservoir would flood critical moose habitat and because the area has great aesthetic value. Therefore, the Wise River site was dropped.

DNRC recommends that a dam be built at the Pattengail site. Because stored water from a Pattengail reservoir could be released from mid-July to September, the project could improve the dewatering problem in the Wise River and the Big Hole as well as provide water for irrigation in the basins of the Wise River, the lower Big Hole, and the Jefferson. The reservoir's firm annual yield would be sufficient to add 170 cfs (10,140 acre-feet) for one month to instream flows (or any distribution thereof) and irrigate 4,352 acres. In an average year, this would be sufficient to eliminate 73% of the shortages for currently irrigated lands and to provide a maintenance-level habitat for the fishery in the Wise River and lower Big Hole. In a dry year (the driest year in ten), stored water from Pattengail could relieve 26% of the total shortage.



INTRODUCTION

There never has been anything meager about the Big Hole of southwestern Montana. Its history is peopled with trappers and traders, and with bitter Nez Perce warriors who gave ground mile after bloody mile before a relentless U.S. Cavalry in 1877. The valley itself is commanding, spreading from the Bitterroot Mountains on the west to the Pioneer Mountains on the south and east. It was named by exploring mountain men who, referring to any mountain valley as a "hole," called this valley the big one.

There is nothing meager about Big Hole water problems, either. The Big Hole River is mountain-born south of the main Big Hole valley and wanders through the basin, fed by a number of tributaries, to flow into the Beaverhead River near Twin Bridges. During summer months, when the river has been known to slow to a trickle, there isn't enough water in it to meet competing needs. The basic competition is between use of the river for recreation and use of the river for irrigation of crops.

Seeking a solution to the problem, the Montana Senate and House of Representatives, in 1977, passed House Joint Resolution 80 directing the Montana Department of Natural Resources and Conservation to look into the possibilities of building water storage reservoirs to serve Big Hole basin water uses.

By December 1978, DNRC had investigated 120 possible storage sites and had prepared a report describing the twenty-two sites that had survived the process of elimination and were worth further consideration (Montana DNRC 1978). The legislature then passed HB 824, based on information from the 1978 report, directing DNRC to conduct a water demand survey in the Big Hole and Jefferson basins and to complete further study of the eight tributary storage sites that had the greatest potential of providing enough water to solve the shortage problem.

In response to that bill, DNRC surveyed the basins's irrigators to find out how many could use additional water if it were made available in the mainstem. DNRC also established the time, location, and quantity of current water shortages, which were identified using streamflow records and calculated irrigation and instream requirements. The potential tributary storage sites were investigated for feasibility. Water rental, ground water, and water conservation were considered as alternative solutions to water shortage problems.

This report presents the results of that work. Chapter I consists of a short description of the river, the basin, and the uses to which they are put. Chapter II quantifies current and potential water uses and shortages in the basin. Possible solutions to the basin's water availability problems are considered in chapter III; DNRC's recommended solution is presented in chapter IV.

I. THE BIG HOLE BASIN

PHYSICAL CHARACTERISTICS OF THE BASIN

Traditionally, what is referred to as the Big Hole is the upper Big Hole basin. In fact, the Big Hole is divided into two portions: the upper basin takes in everything upstream from the Melrose gaging station (about 7 miles downstream from Melrose) including the Wise River drainage; the lower basin includes all of the watershed from the Melrose gaging station downstream to the river's confluence with the Beaverhead River (figure 1). The upper basin includes 2,476 square miles of watershed compared to 317 square miles in the lower basin, for a total of 2,793 square miles.

The Big Hole River basin is bounded by the Bitterroot and Pioneer mountains. In general, the mountainous portions of the Big Hole River basin are forested and the mountain valleys grow grass and sagebrush. Subirrigated portions of the basin floor along the Big Hole River valley and the river's major tributaries are grasslands vegetated with native grass hays. Upland terraces grow Idaho fescue and green needlegrass in the upper valley and needle-and-thread in the lower, merging into sagebrush in the foothills along the mountains and in the higher mountain valleys.

The Big Hole is a rural area of small towns and widely scattered ranches. The population centers are Jackson (population 82), Wisdom (154), and Wise River (100) in the upper basin and Divide (121), Melrose (218), and Glen (40) in the lower.

The lower Big Hole basin is served by Interstate 15. State Highway 43 follows the course of the river from Divide to Wisdom where it turns west over Chief Joseph Pass to connect the upper Big Hole River basin with Salmon, Idaho, 72 road miles south, and Hamilton, Montana, 71 road miles north. Jackson is served by Route 278 from Wisdom to Dillon. The basin has no railroad, and air service depends on a small runway at Wisdom.

CLIMATE

The climate in the basin is harsh—that of a high mountainous region. Weather stations at Wisdom and Twin Bridges represent the climatic conditions of the Big Hole River valley floor. Temperature extremes at Wisdom in 1978 were a high of 88 degrees (°F) and a low of -50 degrees compared to 92 degrees and -31 degrees at Twin Bridges. Annual precipitation averages 12 inches at Wisdom and 9 inches at Twin Bridges. There is abundant runoff in the spring followed by greatly reduced flows in the late summer, a typical pattern for steep, mountainous drainages.

The growing season is short. National Climatic Center records indicate that from September 28 to May 10, there is a 90% likelihood of frost every day.

LAND USES

Land uses in the Big Hole basin are agriculture, timber production, and recreation. The main agricultural uses are raising livestock (cattle and sheep) and growing crops (hay and alfalfa) to support the livestock industry. Mountainous lands and mountain meadows, both public and private, not planted in hay are used for summer pasture.

Most of the Bitterroot and Pioneer mountains are in the Beaverhead National Forest and are managed for multiple use, particularly timber harvest and recreation. Camping, hiking, fishing, hunting, and other outdoor activities are enjoyed by Montana residents and out-of-state visitors. Mining in the Big Hole fluctuates with the metal and commodity market. The Big Hole has deposits of gold, silver, lead, zinc, manganese, and tungsten. It also has phosphate, thorium and rare earths, and construction minerals such as limestone, dolomite, quartzite, and mineral aggregates.

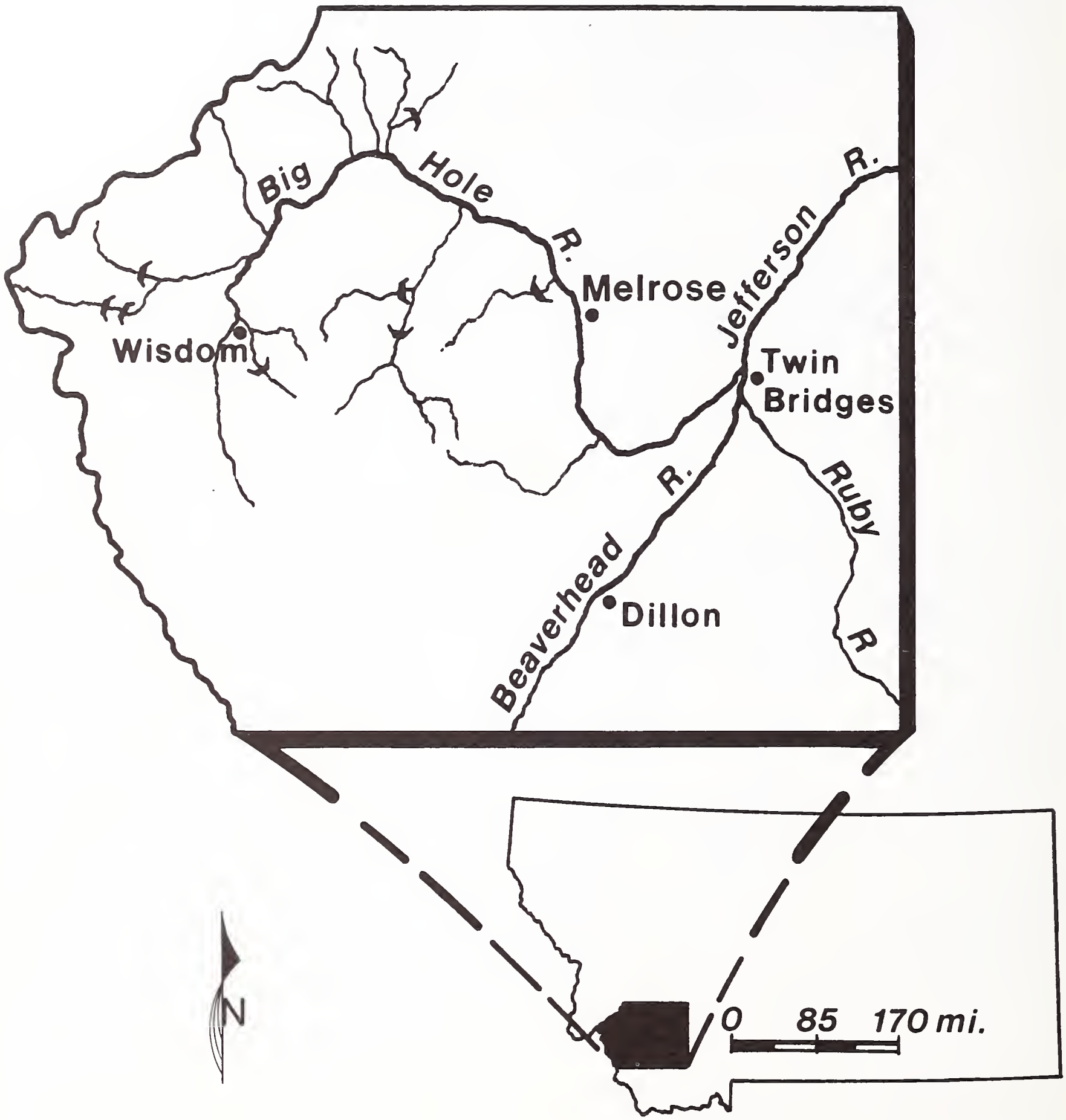


FIGURE 1 BIG HOLE BASIN.

In recent months there has been limited oil exploration in the upper basin. Amoco Production Company is drilling a wildcat well on a ranch 6 miles southwest of Wisdom. Company spokesmen have said that noncommercial amounts of gas were found at 14,000 feet. The area is part of the Montana "overthrust belt" thought by some geologists to have potential as a source of domestic oil and natural gas.

WATER SUPPLY

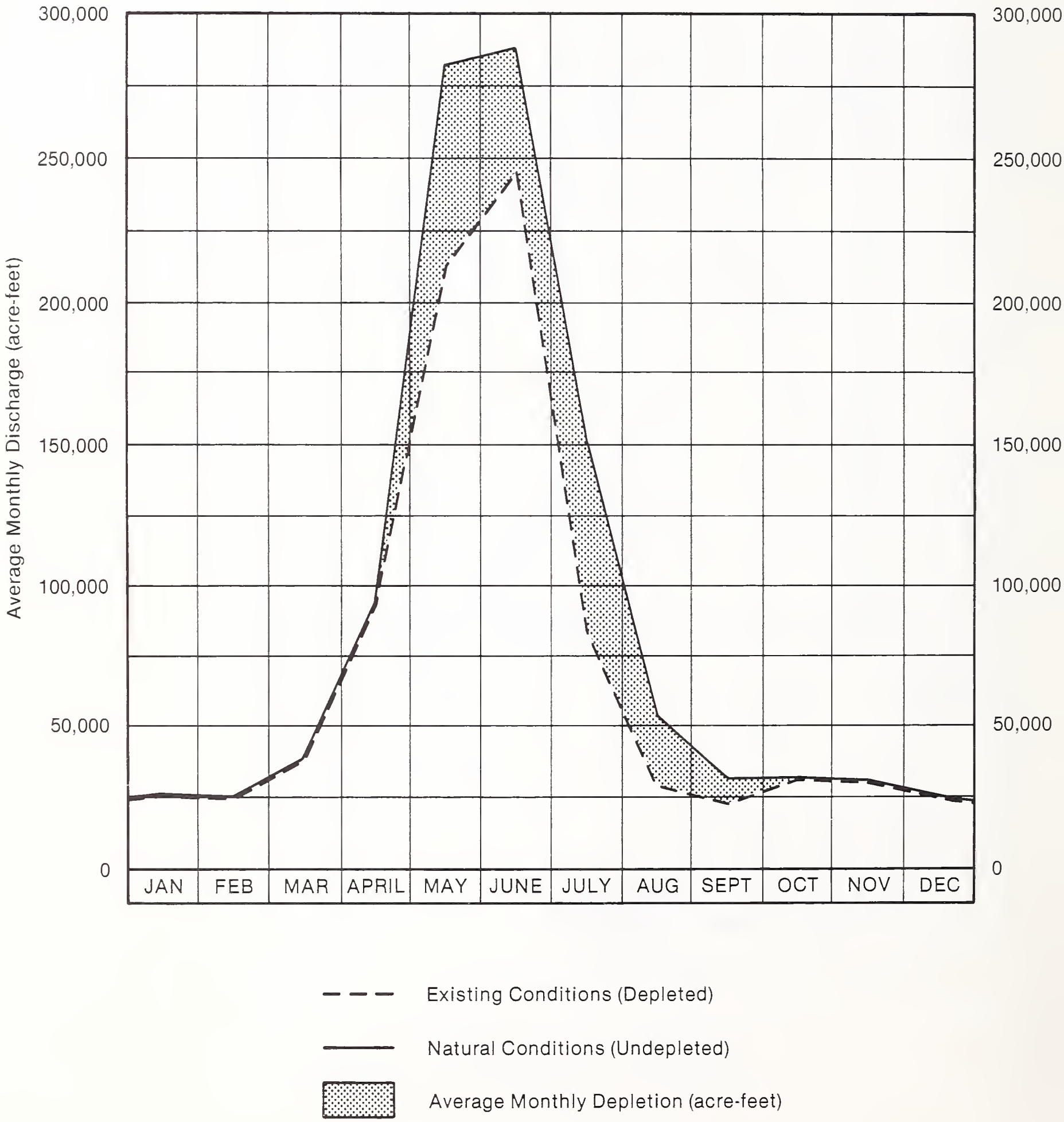
The water supply to the upper basin, based on gaging station records, is 842,500 acre-feet per year. Those records, of course, do not include upstream depletions for consumptive use. Addition of the estimated average annual depletions to the recorded flows at Melrose show an estimated natural (before any consumptive use) average annual flow of 1,058,591 acre-feet per year for the upper basin. Estimated average annual inflow to the Big Hole from tributaries in the lower basin is 73,781 acre-feet. A summary of the average annual water supply for the Big Hole basin is shown on table 1 and figure 2.

Table 1: Average annual water supply of the Big Hole River basin. (All values are in acre-feet.)

MONTH	UPPER BASIN		LOWER BASIN	TOTAL OF NATURAL FLOWS FOR BOTH BASINS
	Recorded	Natural	Natural	
January	21,555	21,555	1,477	23,032
February	20,447	20,447	1,195	21,642
March	27,849	27,849	1,576	29,425
April	91,821	91,849	2,561	94,410
May	212,522	284,371	12,850	297,221
June	245,702	289,558	24,334	313,892
July	83,957	151,331	12,755	164,086
August	29,886	53,812	7,379	61,191
September	22,792	31,803	2,576	34,379
October	31,252	31,252	3,407	34,659
November	30,201	30,201	2,480	32,657
December	24,591	24,591	1,187	25,778
	842,575	1,058,619	73,777*	1,132,372

*Water from tributaries in lower basin to the Big Hole

FIGURE 2 FLOW OF THE BIG HOLE RIVER AT MELROSE WITH DEPLETED AND UNDEPLETED CONDITIONS. ALL VALUES IN ACRE-FEET



II. USES AND SHORTAGES, NEEDS AND DEMANDS

The Big Hole River is used as a source of irrigation water, as a free-flowing river for fish habitat and recreation, and as a source of municipal water. The greatest demands on the river are for irrigation and for fishing.

The total demand for all uses is 880,832 acre-feet per year, if a maintenance-level aquatic habitat is provided, and 1,115,000 acre-feet per year if an ideal aquatic habitat is provided. This is less than the average annual supply of 1,132,372 acre-feet per year, but all too often the supply is not in the right place at the right time.

Shortages in the water supply to meet use requirements occur for three reasons:

1. Even though the average annual flow is adequate to meet needs, seasonal low flows in months such as August are not.
2. Annual fluctuations from the average flow result in many years of less than the average annual supply.
3. Since 70% of the irrigators in the upper basin use tributary water, they may be water-short even though there is water in the mainstem.

IRRIGATION

Current Irrigation Use

The irrigated agriculture that supports the area's economy depends on water. There are 133,854 irrigated acres in the basin. The estimated average annual diversion requirement for the basin, if present shortages are met, is 381,888 acre-feet, significantly less than the water supply. But, because the water isn't available where and when it's needed, irrigators in the upper basin run short of water in mid to late July of most years, particularly along the tributaries that supply 70% of the irrigation water. Even in the lower Big Hole, some farmers have to reduce their irrigation in one year of three because there isn't enough water.

DNRC's attempt to estimate current water use for irrigation uncovered little existing information. Irrigation in the Big Hole River valley is carried out by ditch companies and individual irrigators. In general, individual irrigators divert from tributary streams, and ditch companies operating for a number of irrigators divert from the mainstem river. Neither individuals nor ditch companies have kept adequate records of annual diversion quantities. In addition, there are a few transbasin diversions; the major one from Willow and Birch creeks into the Beaverhead River basin is estimated to be 25,000 acre-feet per year at most.

DNRC reviewed information from the limited ditch company records available and surveyed sixty-six irrigators on the Big Hole River asking for information about current irrigation practices. Sixty-two responses were received.

Responses to a question regarding the rate of present diversions indicated that the full capacity diversion rate is 2,403 cubic feet per second (cfs) for 35,121 acres. If 2,403 cfs were applied to the 35,121 acres surveyed for a thirty day period in May or June, the monthly application would be 4.07 acre-feet per acre—more than six times the calculated irrigation diversion requirement for that period of time. This projection may be accurate; field observations suggest that the irrigators may, in fact, divert as much as six times the calculated diversion requirement. One reason for this application of excess water is that calculated requirements do not consider rough topography.

Inefficient flood irrigation practices do not, however, contribute to shortages, because most excess water returns rather rapidly overland to the river. Irrigators in the upper basin flood irrigate because the climate supports production of grass hay; crops that would bring a higher return and support more efficient but expensive systems such as sprinkler irrigation will not grow.

Since present diversions aren't measured, the irrigators can only estimate how much water they divert per acre. In order to estimate water shortages, however, these diversion quantities must be known. Therefore, they have been estimated from calculations. In making these calculations,

certain assumptions have been made based on information obtained from the survey:

1. Upper basin crops are predominantly grass hay.
2. Upper basin water supplies are adequate to mid-July and are reduced by two-thirds after that in years of average flows.
3. Lower basin crops are predominantly high-water-using crops such as alfalfa and get a full irrigation water supply in years of average flows.
4. Existing irrigation diversion needs are for providing a full supply of water to both upper and lower basin crops.
5. Existing irrigation depletions are based on the current short supply of water for upper basin crops in years of average flows.
6. Irrigation shortages are the difference between ideal irrigation diversion requirements (number 4 above) and the irrigation diversions under current conditions (number 5 above).

The minimum amount of water needed (not necessarily the amount used) for irrigation in the Big Hole under existing conditions has been calculated using these assumptions. The irrigation diversion requirements for grass hay and alfalfa shown in table 2 are the diversions required to provide a full water supply to the crops with no shortages and are subdivided into surface and sprinkler irrigation.

Irrigation diversions, such as this one on the Big Hole, currently divert unmeasured amounts of water from the river and its tributaries.

Table 2: Summary of full irrigation diversion requirements estimated for the Big Hole River basin.

UPPER BASIN:	**GRASS HAY**	
Crop Irrigation Requirement:	8.52 inches	
	Surface	Sprinkler
Farm Irrigation Efficiency		
Surface Irrigation	50%	—
Sprinkler Irrigation	—	70%
Delivery System Efficiency	60%	60%
Irrigation Diversion Requirement		
In Inches	28.40	20.29
In Acre-feet per Acre	**2.37**	**1.69**

LOWER BASIN:	**GRASS HAY**		**ALFALFA**	
Crop Irrigation Requirement:	10.15 inches		19.21 inches	
	Surface	Sprinkler	Surface	Sprinkler
Farm Irrigation Efficiency				
Surface Irrigation	50%	—	50%	—
Sprinkler Irrigation	—	70%	—	70%
Delivery System Efficiency	60%	60%	60%	60%
Irrigation Diversion Requirement				
In Inches	33.83	24.17	64.03	45.74
In Acre-feet per Acre	**2.82**	**2.01**	**5.34**	**3.81**

The potential return flow from water diverted for irrigation in the Big Hole basin is shown in table 3. Potential return flow is the difference between the irrigation diversion requirement and the total depletion (consumptive use). There are two kinds of return flow—that which returns quickly overland to the source and that which percolates through the soil and enters the ground-water system. Because of the drainage conditions characteristic of alluvial deposits found in the Big Hole basin, return flows that have entered the ground-water system can take several months or more to drain back to the river; it is possible that they do not return within the same season they are diverted.

A DNRC inventory of currently irrigated lands in the Big Hole basin identifies 112,085 acres currently irrigated in the upper basin and 21,769 in the lower basin. Combining upper and lower basins, the total lands now irrigated in the Big Hole are 133,854 acres. Multiplying that acreage by the irrigation diversion requirements of 2.37 and 5.34 acre-feet per acre for the upper and lower basins respectively (table 2) gives a total estimated irrigation diversion for the basin of about 387,767 acre-feet for a full water supply for alfalfa in the lower basin and grass in the upper (figure 3). That is the amount needed to fully irrigate only those lands now being irrigated.

Potential Irrigation Use

To determine the potential for agricultural use of stored water, DNRC considered the following factors that indicate past water demands in the basin. A DNRC survey of irrigators in the basin shows that 50% are irrigating the same number of acres they did twenty years ago and 50% have increased irrigated acreage by an average of three hundred acres each. They report that reasons for the increases in irrigation are increased profits and more dependable yields, not water availability. However, nearly all those surveyed expressed interest in additional water supplies.

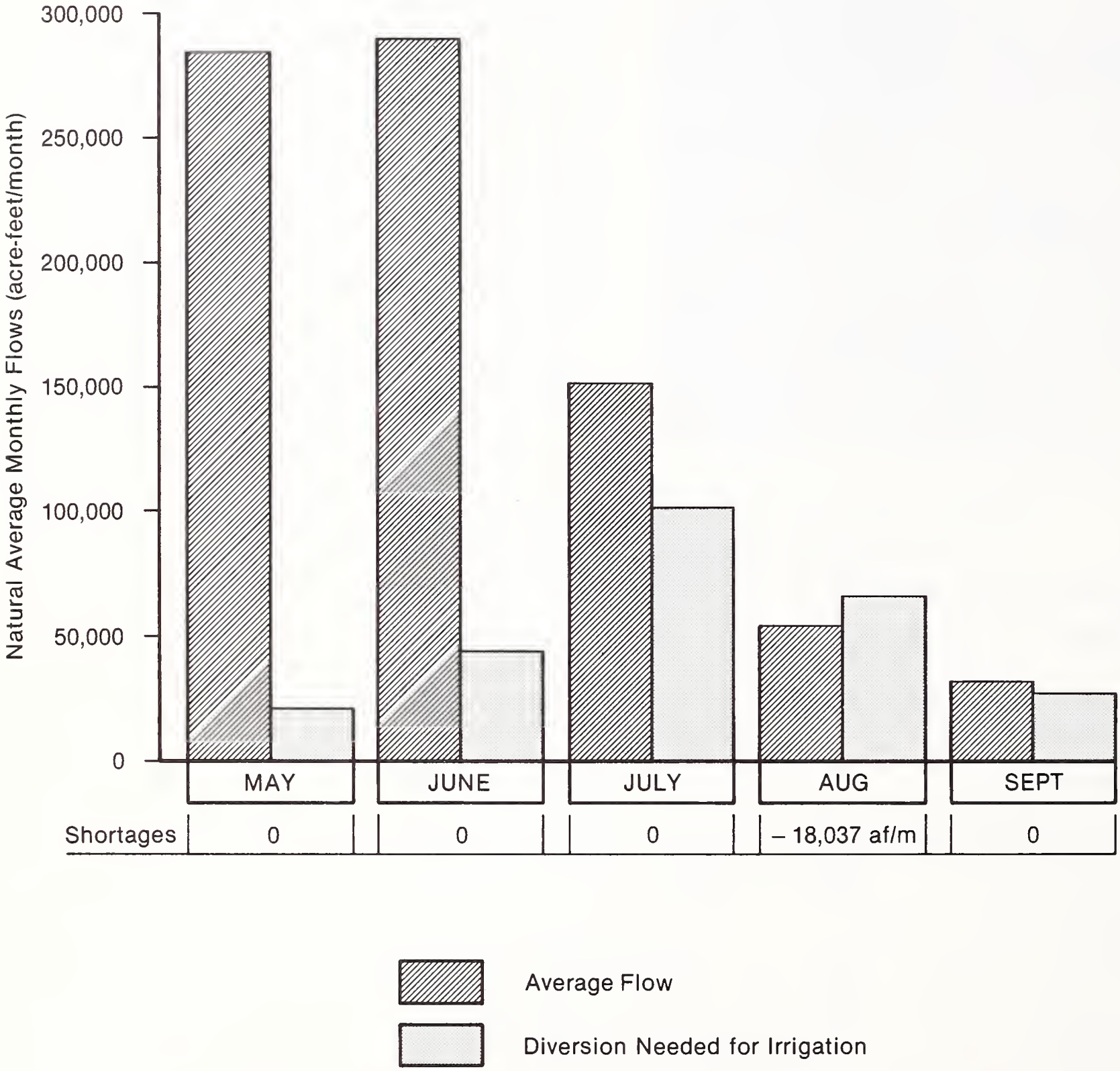
Since 1973, DNRC has received only three applications for water rights permits to irrigate a total of 759 acres in

Table 3: Potential return flow from a full irrigation water supply. (All values are in inches unless otherwise noted.)

UPPER BASIN:	GRASS HAY	
	Surface	Sprinkler
Crop Irrigation Requirement (Table 2)	8.52	8.52
Wind and Spray Loss	0	0.43
Total Consumptive Use	8.52	8.95
Irrigation Diversion Requirement (Table 2)	28.40	20.29
Total Consumptive Use	-8.52	-8.95
Potential Return Flow		
In Inches	19.88	11.34
In Acre-feet per Acre	**1.66**	**0.95**

LOWER BASIN:	GRASS HAY		ALFALFA	
	Surface	Sprinkler	Surface	Sprinkler
Crop Irrigation Requirement (Table 2)	10.15	10.15	19.21	19.21
Wind and Spray Loss	0	0.51	0	1.07
Total Consumptive Use	10.15	10.66	19.21	20.28
Irrigation Diversion Requirement (Table 2)	33.83	24.17	64.03	45.74
Total Consumptive Use	-10.15	-10.66	19.21	20.28
Potential Return Flow				
In Inches	23.68	13.51	44.82	25.46
In Acre-feet per Acre	**1.97**	**1.13**	**3.74**	**2.12**

FIGURE 3 MONTHLY IRRIGATION DIVERSION REQUIREMENTS FOR FULL IRRIGATION COMPARED TO NATURAL FLOWS (BEFORE ANY CONSUMPTIVE USE) IN UPPER BASIN UNDER EXISTING CONDITIONS



These calculations assume perfect distribution of available water to areas of shortages. This does not happen so the shortage is understated here.

the Big Hole basin. All three were granted, but the two most recent were provisional so that irrigation must stop on July 30 of each year. There have been no applications for permits in the last three years, but scarcity of applications may not reflect actual interest in new water use. Instead, it may reflect an awareness that the Water and Power Resources Service and Montana Power Company object to nearly every application for a new consumptive use above Canyon Ferry Reservoir because of their hydropower rights, and that there are decrees (rights granted as a result of a water right lawsuit and usually indicating a water availability conflict) on many of the Big Hole tributaries.

An inventory of irrigable lands identifies 79,533 acres of irrigable land not now irrigated in the upper basin and 5,912 acres in the lower basin, for a total of 85,445 acres. When water supply and economics are considered, the number of irrigable acres drops from 85,445 to 45,405 that are within 1¼ miles of water and require a pumping lift of 200 feet or less. This distance and lift are guidelines used to define irrigable lands that are economically feasible to irrigate at this time. Responses to DNRC's survey show that irrigators are interested in developing nearly all of their irrigable lands. Developing all economically feasible irrigable acreage would require an additional 93,598 acre-feet per year in the upper basin and 22,482 acre-feet in the lower basin.

Although lack of water is an important block to increased agricultural development in the Big Hole, climate plays a major role as well. The short, cool growing season limits the types of crops to grass hay, alfalfa, and some small grains. Since crop potentials are limited by climate to some of the lower-revenue producing crops, increased irrigated acreage might not pay the additional cost of irrigation expansion, especially for the more expensive sprinkler systems.

Shallow ground water under much of the irrigated land also affects crop productivity. Shallow ground water in the root zone of the crops results in low yields, and storage to provide more irrigation water will not solve this problem. It will be necessary to manage the timing of irrigation water application and to control the water table.

In addition to the short growing season and shallow ground-water conditions that affect productivity, the demand for additional irrigation water from the Big Hole River is influenced by cost. The net income per acre of $11.49 for flood irrigated land and $10.02 for sprinkler irrigated (Cooperative Extension Service 1978) shows how much farmers can afford to pay for irrigation water under current conditions. (It should be noted that these data are not up-to-date.) Also, research results indicate that with proper management of irrigation water application, careful selection of crop types, and use of nitrogen and phosphate fertilizers the productivity of the high mountain meadows in the upper Big Hole River basin may be increased to as much as 4 tons of hay per acre. According to responses to the DNRC questionnaire, average yields per acre in the Big Hole are 1.0 ton at Wisdom, 1.1 at Wise River, 2.2 at Divide, 2.3 at Twin Bridges, 2.4 at Melrose, and 2.8 at Glen.

Irrigation Shortages

The DNRC questionnaire responses show that irrigators in the upper basin begin to run short of irrigation water by mid to late July in most years; that the shortages amount to about two-thirds of the water needed in the upper basin in the last half of July and in August and September; that irrigators either reduce the amount of irrigation water applied per acre or reduce the number of acres irrigated and maintain the full application rate on the reduced acreage. The questionnaire data show that irrigators in the lower basin suffer water shortages in one of three years. However, the irrigation requirement is satisfied in some years at the expense of instream flows, and irrigators do not have enough water to develop additional acreages.

During periods of extremely low flows, some irrigation diversions along the Big Hole are left high and dry.

The shortages are related only in part to methods used to divert irrigation water from the river. In some cases, diversion structures cannot divert enough water even though there is enough water in the river to supply the diversion requirement; diversion structures require a minimum river stage in order to divert water. However, shortages would exist even if the structures were improved. Diversion structures simply move water to different places; they cannot increase supply.

The questionnaire data reveal a 99,631-acre-foot irrigation diversion shortage, while the shortage illustrated in figure 3 is 18,037 acre-feet. The real shortage (99,631 acre-feet) is larger than the calculated shortage (18,037 acre-feet) because an estimated 70% of upper basin irrigators divert from tributaries that have flows adequate to satisfy irrigation diversions only in May and June during peak snowpack runoff. Flows in the tributaries diminish or stop completely by late July, and will irrigate, at best, only a small portion of upper basin lands.

In contrast, flows in the mainstem river, although also reduced, still provide a fair amount of irrigation water. Most of the water in the late irrigation season is available only from the mainstem river, where only 30% of the diversions occur. As discussed earlier, there are irrigation shortages in approximately one year of three for users of the ditches lowest on the river. There are no shortages currently reported in the Jefferson basin from Twin Bridges to Whitehall, although additional acreage in the area could be developed if new water supplies were available.

INSTREAM

Current Instream Use

In 1980, the entire Big Hole River received the highest possible rating in the Department of Fish, Wildlife and Parks' fishery classification system. This rating defines the Big Hole as having the "highest-valued fishery resource." The Big Hole River is second only to the Madison in fishing pressure in the upper Missouri basin and gets 66,000 fisherman-days of use in a typical year. The river is also used for canoeing, rafting, and camping, and these uses, along with fishing, bring substantial economic benefit to the area.

The amount of water left flowing in the river, as much as anything, will determine how good a fishery the Big Hole River will be. Water quality, habitat quality, the number of fish, and their size are directly related to the amount of instream flow. The following statement from the Department of Fish, Wildlife and Parks (DFWP) defines two categories it uses to distinguish fish habitat:

> High Level of Aquatic Habitat Potential—That flow regime which will consistently produce abundant, healthy and thriving aquatic populations. In the case of game fish species, these flows would produce abundant game fish populations capable of sustaining a good to excellent sport fishery for the size of stream involved. For rare, threatened or endangered species, flows to accomplish the high level of aquatic habitat maintenance would: 1) provide for high population levels to ensure the continued existence of that species or, 2) provide for flow levels above that which would adversely affect the species.
>
> Low Level of Aquatic Habitat Potential—Flows to accomplish the low level of aquatic habitat maintenance would provide for only a low population abundance of the species present. In the case of game fish species, a poor sport fishery could still be provided. For rare, threatened or endangered species, their populations would exist at low or marginal levels. In some cases, this flow level would not be sufficient to maintain certain species.

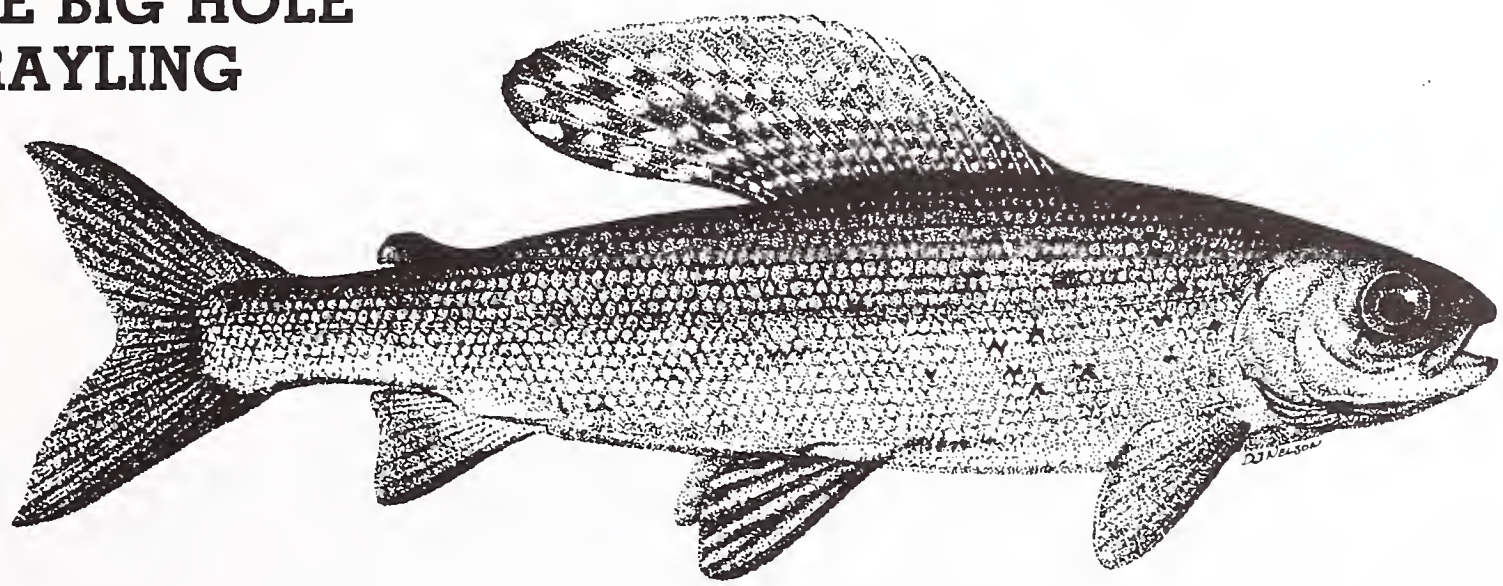
Recreationists visiting sites like Sportsmen Park on the Big Hole add substantially to the area's economy.

Both of the levels defined above have been calculated for the Big Hole River by DFWP. The "high-level" habitat exceeds the natural flow of the Big Hole (the amount of water that would be in the river if there were no diversions) in most months. The "low-level" habitat is maintained in the upper river (above Melrose), but exceeds the existing flow in the lower river some months of most

years. To acknowledge that the river is classified as a blue-ribbon fishery with flows lower (in some cases) than those described above, in this report the "high-level" habitat will be called ideal habitat, and the "low-level" habitat will be called maintenance-level habitat.

Current river reclassification by DFWP shows that the Big Hole fishery has decreased in quality due to dewatering since its blue-ribbon designation in the late 1950s. Populations of both brown and wild rainbow trout fluctuate in response to instream flows; the wild rainbow trout population in the Big Hole River has been reduced by periodic depletions of instream flow. Besides maintaining trout habitat, an ideal habitat is needed to sustain populations of rare, threatened, or endangered species such as the grayling discussed below. A maintenance-level habitat may result in elimination of the grayling population.

THE BIG HOLE GRAYLING



The most unique users of the Big Hole River, perhaps, are the grayling. The upper Big Hole serves as habitat for the last sizable population of arctic grayling native to a river in the lower 48 states. These strikingly colorful fish, rare or nonexistent elsewhere in America (except Alaska), are one of Montana's historical and natural treasures.

The grayling were brought to the Big Hole not by man (as the rainbow and brown trout were) but by the last great glaciation of the Ice Age, roughly 10,000 years ago. When white settlers began crossing the continent during the eighteenth and nineteenth centuries, two separate populations of grayling were thriving along the northern U.S. border—one population in Michigan, and one in the upper Missouri drainage of Montana, including the Big Hole.

Both the Michigan and the Montana grayling were what is known technically as glacial relicts, meaning they had been pushed southward into open water ahead of the glaciers, and then left behind in these two isolated pockets when warmer ages arrived and the ice melted back. Grayling evolved as arctic fish and need clear, cold water to survive.

In Michigan they didn't survive. Saw logs floating downriver disturbed their spawning beds, streambanks were cleared of vegetation, water temperatures consequently rose, non-native competing fish were introduced, and by 1940 the Michigan grayling was extinct.

In Montana also, grayling have largely disappeared from their native rivers. Today they are rarely if ever found in the Madison, the Jefferson, the Gallatin, the Smith, or the Sun. Only in the Big Hole—and to a lesser degree in the Red Rock River of the Centennial Valley—do Montana grayling survive in numbers.

But now there is concern over how long the Big Hole population can hold on with the current conditions of water demand and rising summer stream temperatures. Its continuing presence in the upper Big Hole River is of interest to scientists, fishermen, tourists, and natural historians. If Montana loses the Big Hole grayling, it will have lost something precious, and irreplaceable.

Potential Instream Use

DFWP has concluded that flows satisfying instream needs in the blue-ribbon reach (the 51 miles from the mouth to the old Divide dam), which has the largest instream flow needs, can be considered to meet instream needs for the rest of the river as well. Instream flow needs in the blue-ribbon reach total 521,995 acre-feet per year for a maintenance-level fish habitat and 684,998 acre-feet per year for an ideal habitat. There would be enough water to meet these needs in seven years of ten in the month of the lowest flows if there were no irrigation in the lower basin. But when irrigation needs in the lower basin are met, there is adequate water in only three years of ten.

Instream Shortages

Instream flow requirements for both maintenance-level and ideal habitat are compared to average monthly flows at the Melrose gaging station on figure 4. These data show that the instream flows needed for the ideal habitat exceed the long-term average monthly discharge occurring in seven out of twelve months. This is because the ideal habitat is defined as providing the highest possible fishery potential, and low flows, even naturally low flows, can be destructive to habitat and decrease the quality of the fishery.

Figure 4 also shows that, in an average year, there are no instream shortages for a maintenance-level habitat in the upper basin.

There are instream shortages for a maintenance-level habitat in the lower basin in seven years of ten.

MUNICIPAL

Current Municipal Use

A relatively small amount of water is taken from the Big Hole River for municipal uses. The largest municipal user is the Butte Water Company, which diverts water from the river near the old Divide Dam through two 26-inch and one 36-inch pipelines. Although the maximum capacity of the three pipelines is about 25 million gallons per day (mgd), the present pumping plant capacity is about 12 mgd (13,464 acre-feet per year). The amount of water diverted from the Big Hole River for the past ten years has ranged from 6 to 10 mgd. Other communities in the basin (Jackson, Wisdom, Wise River, Divide, and Melrose) rely on both ground water and surface water (table 4). However, municipal water uses, even when all municipal users are combined, are negligible in comparison to irrigation and instream uses.

Potential Municipal Use

Butte Water Company currently uses 13,441 acre-feet of water a year (the limit of the pumping plant), but has pipeline capacity to carry about twice that amount. But because rapid population growth is not predicted for any of the communities using Big Hole water, increased municipal use is not anticipated. Municipal use is expected to remain small relative to other uses.

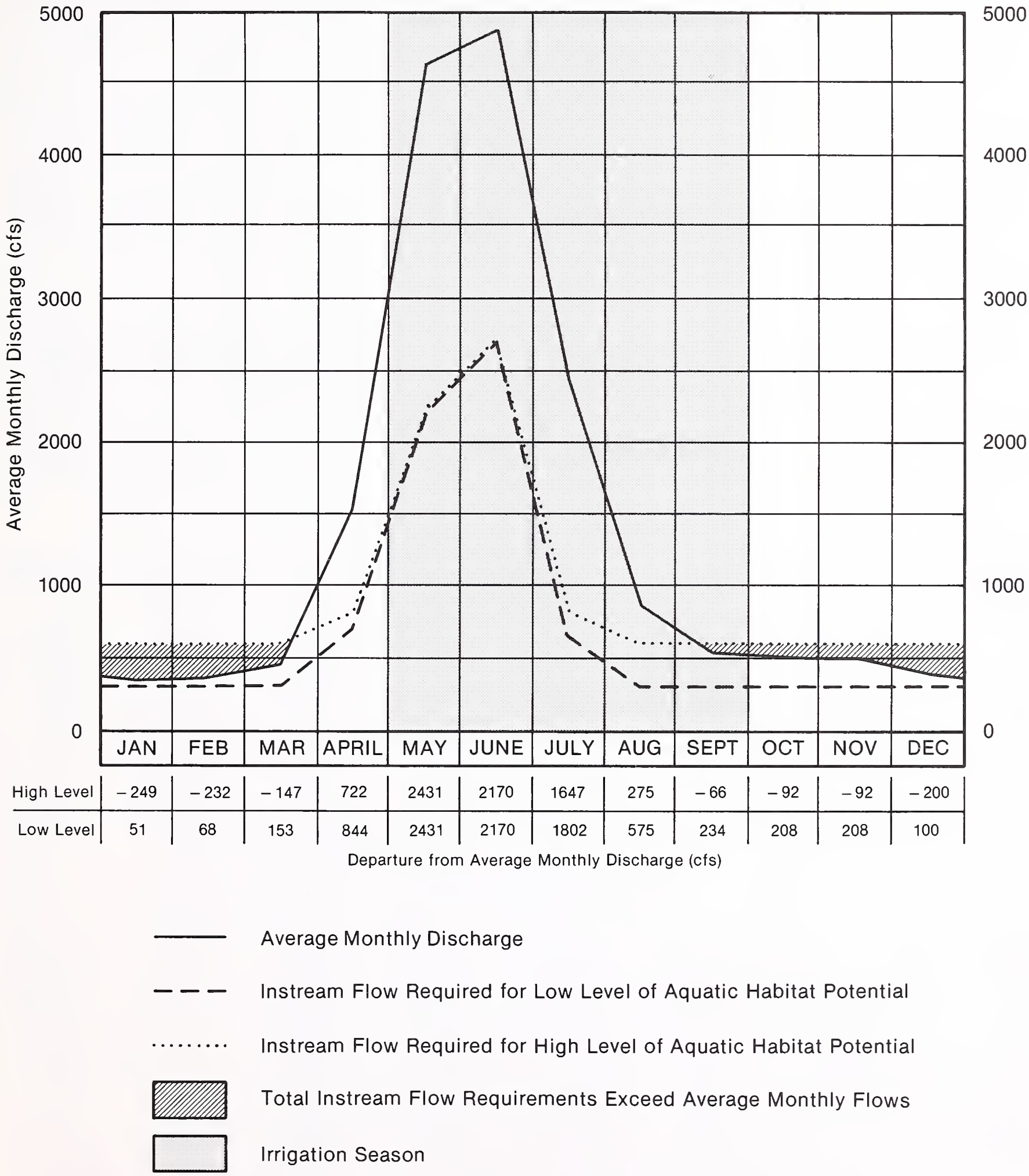
Municipal Shortages

Water supplies in the Big Hole River are adequate to satisfy current municipal uses. Historically, there have been periods of low streamflow where competitive use of the water, primarily for irrigation, has almost completely dewatered a reach of the river. Small water users, such as Big Hole municipal users, are affected by a shortage less than large water users unless the river is totally dry.

Table 4: Municipal water use requirements for the Big Hole River basin.

TOWN	GALLONS/DAY	ACRE-FEET/YEAR
Butte	12,000,000	13,464
Divide	30,250	34
Jackson	20,500	23
Melrose	54,500	61
Wisdom	38,500	43
Wise River	25,000	28
Total:	12,168,750	13,653

FIGURE 4 HYDROGRAPHS COMPARING MAINTENANCE-LEVEL AND IDEAL AQUATIC HABITAT POTENTIAL INSTREAM FLOW REQUIREMENTS TO MEAN MONTHLY DISCHARGE (ADJUSTED TO NATURAL FLOW) AT MELROSE, MONTANA



	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
High Level	– 249	– 232	– 147	722	2431	2170	1647	275	– 66	– 92	– 92	– 200
Low Level	51	68	153	844	2431	2170	1802	575	234	208	208	100

Departure from Average Monthly Discharge (cfs)

EFFECT OF COMBINED SHORTAGES

The effect of water shortages in the Big Hole basin varies according to when and where they occur. In the lower basin, shortages affect instream flows first and then irrigation and are most severe in August and September. Irrigators in the lower basin report insufficient water supplies in three years of ten. There are instream shortages in an additional four years of ten. Therefore, there is insufficient water to meet all needs in seven years of ten. In the upper basin, shortages affect irrigation from mid-July through September in an average year and occur on tributary streams.

Table 5 and figure 5 show that when all uses in the upper basin are combined, shortages exist from July through September if maintenance-level habitat conditions are met and exist nine months of the year if requirements are satisfied for ideal habitat. Table 6 shows the instream shortages that would occur in the upper basin if an ideal habitat were maintained. There are no shortages in April, May, or June. In July, the only shortage is for irrigation; from October through March all shortages are for instream needs. Under maintenance-level habitat conditions, all shortages are for irrigation.

Table 7 shows the average shortages in the lower Big Hole River basin. Under maintenance-level habitat demands, shortages exist only in August and September when the inflow is low and irrigation demands are high. Under ideal habitat conditions, shortages occur in all months except from April to July, when the inflow is highest. From October through April, there are no irrigation demands and all shortages are for instream use.

Table 5: Occurrence of shortages under maintenance-level and ideal habitat conditions if all current demands were to be met by existing average annual Big Hole River water supplies. (All values are in acre-feet, unless otherwise indicated.)

MONTH	DEMANDS				SUPPLY	SURPLUS OR DEFICIT	
	Irrigation	Instream	Municipal	Total		(Acre-feet)	(cfs)
MAINTENANCE-LEVEL FISH HABITAT							
January	0	18,442	2,001	20,443	23,032	2,589	42
February	0	16,657	2,001	18,658	21,642	2,984	54
March	0	18,442	2,001	20,443	29,425	8,982	146
April	0	41,584	2,001	43,585	94,382	50,797	854
May	47,878	134,896	2,001	184,775	297,222	112,447	1,829
June	62,481	160,442	2,883	225,806	313,892	88,086	1,480
July	136,462	40,512	2,883	179,857	164,086	-15,771	-256
August	100,572	18,442	2,883	121,897	61,192	-60,705	-987
September	33,772	17,847	2,001	53,620	34,379	-19,241	-323
October	0	18,442	2,001	20,443	34,660	14,217	231
November	0	17,847	2,001	19,848	32,682	12,834	216
December	0	18,442	2,001	20,443	25,778	5,335	87
	381,165	521,995	26,658	929,818	1,132,372	202,554	
IDEAL FISH HABITAT							
January	0	36,884	2,001	38,885	23,032	-15,853	-258
February	0	33,314	2,001	35,315	21,642	-13,673	-246
March	0	36,884	2,001	38,885	29,425	- 9,460	-154
April	0	50,507	2,001	52,508	94,382	41,874	704
May	47,878	134,896	2,001	184,775	297,222	112,447	1,829
June	62,481	160,442	2,883	225,806	313,892	88,086	1,480
July	136,462	50,031	2,883	189,376	164,086	-25,290	-411
August	100,572	36,884	2,883	140,339	61,192	-79,147	-1,287
September	33,772	35,694	2,001	71,467	34,379	-37,088	-623
October	0	36,884	2,001	38,885	34,660	- 4,225	- 69
November	0	35,694	2,001	37,695	32,682	- 5,013	- 84
December	0	36,884	2,001	38,885	25,778	-13,107	-213
	381,165	684,998	26,658	1,092,821	1,132,372	39,551	

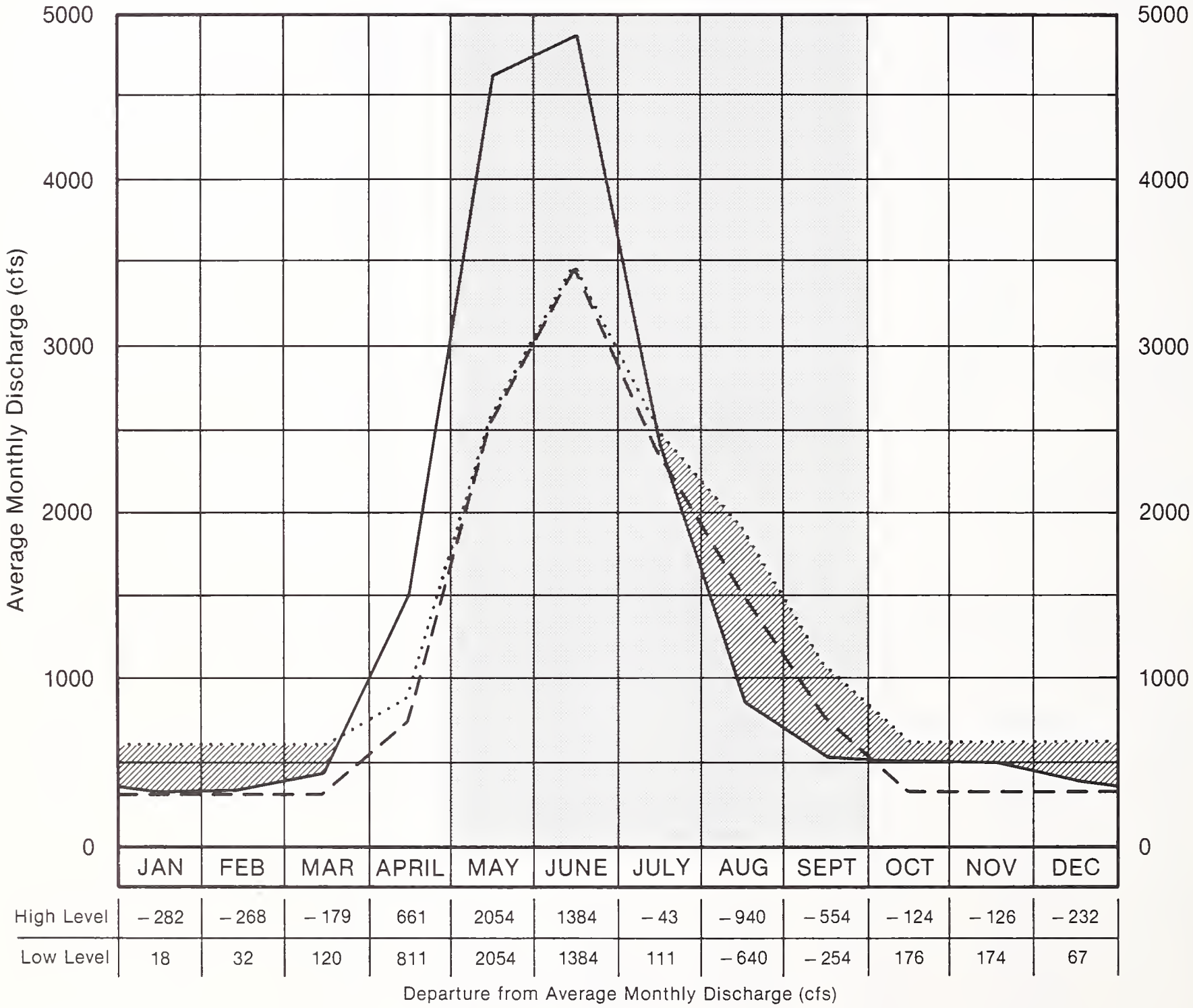
Table 6: Average monthly water shortages in the upper Big Hole River basin under existing conditions. (All values are in acre-feet.)

MONTH	IRRIGATION DEMAND	IRRIGATION DELIVERY	IRRIGATION SHORTAGE	INSTREAM SHORTAGES, MAINTENANCE-LEVEL HABITAT	INSTREAM SHORTAGES, IDEAL HABITAT	TOTAL SHORTAGES, MAINTENANCE-LEVEL HABITAT	TOTAL SHORTAGES, IDEAL HABITAT
January	0	0	0	0	17,330	0	17,330
February	0	0	0	0	14,868	0	14,868
March	0	0	0	0	11,036	0	11,036
April	0	0	0	0	0	0	0
May	21,150	21,150	0	0	0	0	0
June	43,856	43,856	0	0	0	0	0
July	101,087	67,374	33,713	0	0	33,713	33,713
August	71,849	23,926	47,923	0	9,881	47,923	57,804
September	27,060	9,011	18,049	0	14,903	18,049	32,952
October	0	0	0	0	7,633	0	7,633
November	0	0	0	0	7,494	0	7,494
December	0	0	0	0	14,294	0	14,294
TOTAL SHORTAGES:			99,685	0	97,439	99,685	197,124

Table 7: Average monthly water shortages in the lower Big Hole River basin under existing conditions. (All values are in acre-feet.)

MONTH	NATURAL INFLOW TO THE LOWER BASIN	IRRIGATION DEMAND	INSTREAM DEMAND WITH MAINTENANCE-LEVEL HABITAT	TOTAL DEMAND WITH MAINTENANCE-LEVEL HABITAT	INSTREAM DEMAND WITH IDEAL HABITAT	TOTAL DEMAND WITH IDEAL HABITAT	SHORTAGES WITH MAINTENANCE-LEVEL HABITAT	SHORTAGES WITH IDEAL HABITAT
January	21,031	0	18,442	18,442	36,884	36,884	0	-15,853
February	19,641	0	16,657	16,657	33,314	33,314	0	-13,673
March	27,424	0	18,442	18,442	36,884	36,884	0	- 9,460
April	92,381	0	41,854	41,854	50,507	50,507	0	0
May	223,372	26,727	134,896	161,623	134,896	161,623	0	0
June	267,153	18,625	160,442	179,067	160,442	179,067	0	0
July	93,829	35,375	40,512	75,887	50,031	85,406	0	0
August	34,383	28,723	18,442	47,165	36,884	65,607	-12,782	-31,224
September	23,377	6,712	17,847	24,559	35,694	42,406	- 1,182	-19,029
October	32,659	0	18,442	18,442	36,884	36,884	0	- 4,225
November	30,681	0	17,847	17,847	35,694	35,694	0	- 5,013
December	23,777	0	18,442	18,442	36,884	36,884	0	-13,107
TOTAL SHORTAGES:							-13,964	-111,584

FIGURE 5 HYDROGRAPHS COMPARING AVERAGE MONTHLY FLOWS AT MELROSE, MONTANA, AS ADJUSTED TO NATURAL FLOW, TO FLOW REQUIREMENTS FOR INSTREAM USE, MUNICIPAL SUPPLY, AND FULL WATER SUPPLY TO PRESENTLY IRRIGATED LANDS FOR MAY THROUGH SEPTEMBER FOR GRASS CROPPING



	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
High Level	– 282	– 268	– 179	661	2054	1384	– 43	– 940	– 554	– 124	– 126	– 232
Low Level	18	32	120	811	2054	1384	111	– 640	– 254	176	174	67

Departure from Average Monthly Discharge (cfs)

Average Monthly Discharge

Total Flow Requirement at Low Level Aquatic Habitat Potential

Total Flow Requirement at High Level Aquatic Habitat Potential

Total Flow Requirements Exceed Average Monthly Discharge

Irrigation Season

WATER SHORTAGES FOR FIVE POSSIBLE CIRCUMSTANCES

The total demands for instream, irrigation, and other uses of water for the Big Hole basin as a whole have been calculated for five levels of development.

Development Level 1 represents existing conditions and is based on 112,085 irrigated acres in the upper basin and 21,769 irrigated acres in the lower basin. The upper basin crop is grass hay, and lower basin crops are alfalfa or other crops with relatively high consumptive water use. Irrigation methods are assumed to be primarily flood irrigation for both basins, and the average annual water supply is assumed to be reduced to one-third of the irrigation diversion requirements by mid-July each year in the upper basin. Shortages in the upper basin are primarily suffered by irrigation uses and shortages in the lower basin are shared by instream and agriculture.

Development Level 2 represents existing conditions, with a full supply of irrigation water instead of existing short water supplies. The irrigation diversion would be increased by 48,986 acre-feet per year. As shown on table 8, a total shortage of 74,797 acre-feet annually would exist in the lower basin for a maintenance-level fish habitat and a 181,936-acre-foot shortage would exist for an ideal habitat. In the upper basin an annual shortage of 99,685 acre-feet would exist for a maintenance-level habitat, 197,224 acre-feet for an ideal habitat. Upper basin shortages are shown on table 8.

Development Level 3 provides a full supply of irrigation water to the entire basin, like Development Level 2, but with irrigation methods in the lower basin changed from flood to the more efficient sprinkler irrigation. Because sprinkler irrigation is more efficient than flood, the irrigation diversion requirement would be only 15,797 acre-feet more than at present (Development Level 1) and 33,189 acre-feet less than under Development Level 2. In the lower basin, there would be an annual shortage of 54,565 acre-feet under maintenance-level habitat conditions and 161,704 acre-feet under ideal habitat conditions. In the upper basin, with flood irrigation practices unchanged, shortages would be the same as those projected for Development Level 2.

Development Level 4 meets all demands. This level assumes a full supply for all currently irrigated lands and for the 65,170 acres of new land which farmers report as being irrigable. It also assumes that high-yield crops and modern sprinkler irrigation methods would be used on all new lands. At this stage of development there would be 112,085 acres of flood-irrigated grass hay and 59,258 acres of sprinkler-irrigated grass hay in the upper basin, and 21,769 acres of flood-irrigated alfalfa and 5,912 acres of sprinkler-irrigated alfalfa in the lower basin—all with a full water supply. However, use of sprinkler irrigation in the upper basin is unlikely for economic reasons. Projected shortages for Development Level 4 are shown on table 8 for the upper basin and on table 9 for the lower basin. At this high level of development, providing an ideal fish habitat would require an amount of water exceeding the average annual water supply by 544,956 acre-feet a year.

Development Level 5 is the same as Level 4 with the exception of an increase in municipal water demands. Municipal demands would be increased to meet the full 25 mgd capacity of the Butte Water Company pipeline, with an addition of 781 acre-feet per year for other municipal uses. A total municipal demand is projected at 42,000 acre-feet per year for this development level. Under Development Level 5 and with conditions satisfied for an ideal fish habitat, the total potential demand would exceed the average annual water supply by 568,257 acre-feet a year.

Table 8: Projected average monthly water supply shortages in the upper Big Hole River basin. (All values are in acre-feet.)

MONTH	SHORTAGES AT DEVELOPMENT LEVELS 1, 2, 3	ADDITIONAL IRRIGATION DEMAND	SHORTAGES AT DEVELOPMENT LEVEL 4	ADDITIONAL LEVEL 5 MUNICIPAL DEMAND	SHORTAGES AT DEVELOPMENT LEVEL 5
MAINTENANCE-LEVEL FISH HABITAT					
January	0	0	0	1,279	0
February	0	0	0	1,279	0
March	0	0	0	1,279	0
April	0	0	0	1,279	0
May	0	13,168	0	1,279	0
June	0	24,808	0	1,279	0
July	33,713	49,382	83,095	1,279	84,374
August	47,923	35,860	83,783	1,279	85,062
September	18,049	14,815	32,864	1,279	34,143
October	0	0	0	1,279	0
November	0	0	0	1,279	0
December	0	0	0	1,279	0
TOTAL SHORTAGES:	99,685		199,742		203,579
IDEAL FISH HABITAT					
January	17,330	0	17,330	1,279	18,609
February	14,868	0	14,868	1,279	16,147
March	11,036	0	11,036	1,279	12,315
April	0	0	0	1,279	0
May	0	13,168	0	1,279	0
June	0	24,808	0	1,279	0
July	33,713	49,382	83,095	1,279	84,374
August	57,804	35,860	93,664	1,279	94,943
September	32,952	14,815	47,767	1,279	49,046
October	7,633	0	7,633	1,279	8,912
November	7,494	0	7,494	1,279	8,773
December	14,294	0	14,294	1,279	15,573
TOTAL SHORTAGES:	197,224		297,181		308,692

Table 9: Summary of average monthly water supply shortages projected for the lower Big Hole River basin for development levels 2, 3, 4, and 5.
(All values are in acre-feet.)

MONTH	SHORTAGES AT DEVELOPMENT LEVEL 2	SHORTAGES AT DEVELOPMENT LEVEL 3	SHORTAGES AT DEVELOPMENT LEVEL 4	SHORTAGES AT DEVELOPMENT LEVEL 5
		MAINTENANCE-LEVEL FISH HABITAT		
January	0	0	0	0
February	0	0	0	0
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	15,771	5,664	69,994	71,273
August	39,785	31,578	45,357	46,636
September	19,241	17,323	23,285	24,564
October	0	0	0	0
November	0	0	0	0
December	0	0	0	0
TOTAL SHORTAGES:	74,797	54,565	138,636	142,473
		IDEAL FISH HABITAT		
January	15,853	15,853	15,853	17,132
February	13,673	13,673	13,673	14,952
March	9,460	9,460	9,460	10,739
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	25,290	15,183	79,513	80,792
August	58,227	50,020	63,799	65,087
September	37,088	35,170	43,132	44,411
October	4,225	4,225	4,225	5,504
November	5,013	5,013	5,013	6,292
December	13,107	13,107	13,107	14,386
TOTAL SHORTAGES:	181,936	161,704	247,775	259,295

III. POSSIBLE SOLUTIONS

Potential solutions to these shortages include mainstem storage, ground-water development, water conservation, water rental to alleviate instream shortages, and tributary storage.

MAINSTEM STORAGE

The most probable mainstem storage site on the Big Hole River is the Reichle site, located downstream from Glen. This site has been studied by the Water and Power Resources Service (USDI 1958 and 1967), but has not been constructed because of its poor potential economic return. This project has been opposed by a number of sporting and environmental groups for ecological reasons, such as flooding a significant portion of the blue-ribbon stretch. The water from this project was intended for use downstream and would not solve shortages in the upper Big Hole because it is downstream from them. Construction at this site is not recommended.

GROUND-WATER DEVELOPMENT

The use of ground water is an alternative to tributary storage of surface water for relieving present and future water supply shortages.

Unfortunately, information about the distribution, availability, and quality of ground water in the upper basin is limited and out-of-date. The best way of evaluating the potential of ground water in the upper basin is by evaluating what is now known about similar nearby basins. Investigations of nearby valleys have revealed some overall characteristics common to all the valley fills that affect the distribution and availability of ground water.

Water wells in basins geologically like the Big Hole range from 500 to 1,000 feet deep and are producing as much as 1,000 gallons per minute of good-quality ground water from Tertiary sediments. The geology of the upper basin and the surrounding mountain terrain suggests that excellent potential exists to tap ground water in the upper basin. Even so, the distribution and hydraulic properties of the Tertiary ground-water aquifers are still largely unknown, and construction of high-capacity test wells or production water wells in most of the basin remains a high-risk venture.

High-capacity water wells in the upper basin also have the potential to lower ground-water levels. Extensive use of relatively shallow wells for irrigation water, combined with improved irrigation practices, would improve the shallow ground-water conditions that now reduce crop productivity in parts of the basin. Wells for irrigation could possibly make water available throughout the growing season and relieve the annual water shortages that the upper basin now suffers. Although it is likely that abundant ground water is available in parts of the upper basin, there are other points to consider:

1. At present there is not an electrical power distribution system adequate for running pumps.
2. Electricity would probably cost substantially more if the power distribution system were upgraded.
3. Alternative energy sources for ground-water development, such as power generation by windmills, have not been tested in the area.
4. Total annual repayment and operating costs for a well, pipeline and sprinkler equipment, and power are about $55 per acre-foot for 160 acres, assuming average costs in 1980 dollars. Supplying ground water for flood irrigation would be even more costly.

Ground-water development could solve some water shortages in the basin, but it is too expensive to be a practical solution.

CONSERVATION

Potential conservation measures in the Big Hole River basin include reducing the amount of water lost in transport by keeping canals and ditches in good repair, lining canals and ditches to prevent seepage loss, removing water-consuming vegetation from canals and ditches, improving field application efficiency by careful management of total field applications, land leveling, and conversion to sprinkler irrigation methods.

Flood irrigation practices are highly inefficient. Continuous flood irrigation puts far more water on the fields than the crops need in May and June of most years. Since the ground-water system is saturated and moves slowly, most of the excess water diverted returns, rather quickly, overland to the water source. Because it does, flood irrigation does not contribute significantly to water shortages—and for that reason, conserving water in the upper basin would do little to solve the shortage problem.

Irrigation diversion practices are not the cause of low streamflows; low streamflows are caused by the early disappearance of snowpack runoff from tributary streams. It will take more than water conservation to solve water supply problems in the Big Hole. It will take storage to regulate streamflow. However, tributary storage will not increase net irrigated crop productivity unless more efficient irrigation practices and better crop management methods are used.

RENTAL OF IRRIGATION RIGHTS

It would be possible, if some laws were changed, to increase instream flows by renting water rights from irrigators. This water would be rented only when needed at a price negotiated with a current user willing to agree to such an arrangement. The irrigator would retain the water right. This water could be resold downstream by purchasers. Sportsmen and those who represent recreational interests could set up a fund to accomplish this protection of instream flows. Because an implementation plan for a water rental program has not been well developed at this time, DNRC does not recommend this approach in the Big Hole.

TRIBUTARY STORAGE

Potential Of Reservoirs To Reduce Shortages

Storage of more than 575,000 acre-feet of water would be necessary to satisfy all irrigation diversion requirements for a full supply, appropriately distributed, to currently irrigated lands in the upper basin and to provide maintenance-level fish habitat to the upper basin (and therefore the lower) in all years. A total storage of 173,000 acre-feet could be provided if reservoirs were to be constructed on all eight sites considered.

Even if the minimum requirement of 575,000 acre-feet of tributary storage could somehow be developed in the upper basin, none of the stored water would satisfy lower basin irrigation requirements if upper basin irrigation or instream requirements were met first. The only way to use an upper basin tributary reservoir for lower basin needs is to have instream flows bypass upper basin users. Otherwise, irrigators would divert stored water during periods of low flow because they would have no way of identifying water released from storage once it is in a flowing channel. Actually, with storage at any of these sites, assuring delivery of water to those who purchase it will present enforcement problems. It may be necessary for the operators of a reservoir and the local users to cooperate in developing a plan that will assure delivery.

Although no single site will solve all the water shortages in the Big Hole, construction at any of these sites would have a significant impact on reducing the shortage problem. Tables 12 and 13 show that storage at the Wise River and French Creek sites could alleviate shortages in the lower Big Hole by the percentage indicated in an average year. These tables also indicate the number of acres that could be served by this water.

Figures 6 and 7 and table 10 show the acreages that could be served by projects considered here. Nearly all the 112,085 acres currently irrigated in the upper Big Hole need supplemental water and 86,756 of this total could be served by one or more of these projects. Supplemental water is also needed for some of the acreage in the lower basin. There are an additional 45,505 acres of potentially irrigable but not currently irrigated land in the upper and lower basins that could also be served by these projects. New acres that could be put into production and are indicated on these figures are those that fit the current criteria for being economically feasible to irrigate—they are within a 200-foot pumping lift and 1½ miles or less from the water source. Response to DNRC's survey of water users who have land that fits these criteria shows that 98% of the irrigators surveyed are interested in additional water supplies for supplemental water in the upper basin and for developing their irrigable acres in both the upper and lower basins.

Table 10: Acreages that could be irrigated with stored water from one or more of the sites considered.

AREA	IRRIGABLE	IRRIGATED
UPPER BIG HOLE		
Headwaters to Mudd Creek		
Proposed Pump	9,585	0
Sheep & Francis creeks (Below Francis Creek Dam)	0	1,055
Trail & Johnson creeks (Below dam sites and 6200′ contour)	17,805	26,261
Below 200′ Lift and 6500′ contour (Remainder of valley, not included in projects above)	9,151	37,162
Total, headwaters to Mudd Creek	36,541	64,470
Mudd Creek to Maiden Rock		
French Creek (below damsite)	220	252
Below 200′ lift	1,884	3,379
Total, Mudd Creek to Maiden Rock	2,104	3,649
Maiden Rock to Gaging Station		
Below 200′ lift	807	3,827
Total, Maiden Rock to Gaging Station	807	3,827
Total, Upper Big Hole	39,452	71,946
LOWER BIG HOLE		
Gaging Station to Reichle damsite (below 200′ lift)	1,740	4,470
Total, Gaging Station to Reichle	1,740	4,470
Below Reichle damsite to the Beaverhead River (below 200′ lift)	667	7,834
Benchlands	3,505	0
Total, from Reichle damsite to Beaverhead River	4,172	7,834
Total, Lower Big Hole	5,912	12,304
Total, Upper Big Hole	39,452	71,946
Total, Big Hole	45,364	84,250
JEFFERSON RIVER		
Confluence with Big Hole to Boulder River (below 200′ lift)	11,582	14,839
Benchlands	29,098	1,422
Total, Jefferson River	40,680	16,261

Consideration of Specific Sites

Tributary storage is the most feasible solution to water shortage problems in this basin. This report includes evaluations of twenty-two potential tributary storage sites, each of which has a storage capacity of more than 5,000 acre-feet.

A summary of fourteen of the twenty-two sites and the reasons they were eliminated as possible solutions follows in table 11.

Table 11: Summary of reasons for the elimination of fourteen sites from consideration for reservoir storage.

1.	Birch Creek; S.E. ¼, Sec. 23, T. 2S., R. 10W. Site eliminated because the foundation conditions are poor and the development costs are only marginally acceptable.
2.	Deep Creek; Sec. 29, T. 2N., R. 12W. Site eliminated because of highway relocation required; conflict with existing ski hill.
3.	Jacobson Creek; Sec. 34, T. 3S., R. 12W. Site eliminated because of high development costs.
4.	LaMarche Creek; Sec. 5, T. 2N., R. 13W. Site eliminated because of high development costs and encroachment on the Anaconda Pintlar Wilderness.
5.	LaMarche Creek; Sec. 16, T. 2N., R. 13W. Site eliminated because of high development costs and conflict with the LaMarche Creek Guest Ranch.
6.	Pintlar Creek; Sec. 3, T. 1N., R. 15W. Site eliminated because it is entirely within the Anaconda Pintlar Wilderness.
7.	Seymour Creek; Sec. 30, T. 2N., R. 12W. Site eliminated because of high development costs and poor potential for benefits.
8.	Steel Creek; Sec. 3, T. 3S., R. 15W. Site eliminated because of unsuitable geology.
9, 10, 11.	Trail Creek, three sites; S.W. ¼, Sec. 18, T. 2S., R. 17W; N. ½, Sec. 21, T. 2S., R. 17W ; and N. ½, Sec. 5, T. 2S., R. 18W. All three sites eliminated because of the high costs of road relocation.
12.	Wise River; Sec. 20, T. 3S., R. 12W. Site eliminated because of high development costs and because a better site exists on Wise River.
13, 14.	Wyman Creek, two sites; Sec. 25, T. 3S., R. 13W ; and Sec. 34, T. 3S., R. 13W. Sites eliminated because they would not supply water to the lower Big Hole River basin.

Table 12: Regulation, firm annual yield, relief of shortages, and costs per acre-foot for reservoir capacities at the Wise River site.

RESERVOIR CAPACITY (ACRE-FEET)	% OF AVERAGE ANNUAL SUPPLY REGULATED	ACRE-FEET REGULATED	FIRM ANNUAL YIELD (ACRE-FEET)	MINIMUM IRRIGATED ACRES	% OF TOTAL SHORTAGES IN LOWER BASIN WHICH COULD BE ALLEVIATED IN A LOW-FLOW YEAR*	TOTAL COST OF DAM	COST PER ACRE-FOOT (1980 DOLLARS)
10,000	80.6	46,484	19,407	8,329	50	7,235,000	33
15,000	88.2	50,868	24,407	10,475	62	7,466,000	27
20,000	92.8	53,135	24,449	10,493	63	7,697,000	27
50,000	95.6	55,135	25,630	11,000	66	10,121,000	30
75,000	95.6	55,135	25,630	11,000	66	11,807,000	35
100,000	95.6	55,135	25,630	11,000	66	13,586,000	40
125,000	95.6	55,135	27,783	11,924	71	15,440,000	42
150,000	95.6	55,135	51,237	21,990	131	17,252,000	25
175,000	95.6	55,135	51,237	21,990	131	19,116,000	28
200,000	95.6	55,135	51,237	21,990	131	20,944,000	31

*Lowest single year in ten

Table 13: Regulation, firm annual yield, relief of shortages and costs per acre-foot for reservoir capacities at the French Creek site.

RESERVOIR CAPACITY (ACRE-FEET)	% OF AVERAGE ANNUAL SUPPLY REGULATED	ACRE-FEET REGULATED	FIRM ANNUAL YIELD (ACRE-FEET)	MAXIMUM IRRIGATED ACRES	% OF TOTAL SHORTAGES IN LOWER BASIN WHICH COULD BE ALLEVIATED IN A LOW-FLOW YEAR*	TOTAL COST OF DAM	COST PER ACRE-FOOT (1980 DOLLARS)
5,000	92.2	16,556	5,182	2,224	13	4,478,000	68
10,000	95.6	17,167	5,182	2,224	13	6,247,000	93
15,000	95.6	17,167	5,445	2,337	14	7,046,000	99
20,000	95.6	17,167	8,204	3,521	21	7,837,000	73
28,855	95.6	17,167	8,204	3,521	21	10,146,000	114

*Lowest single year in ten

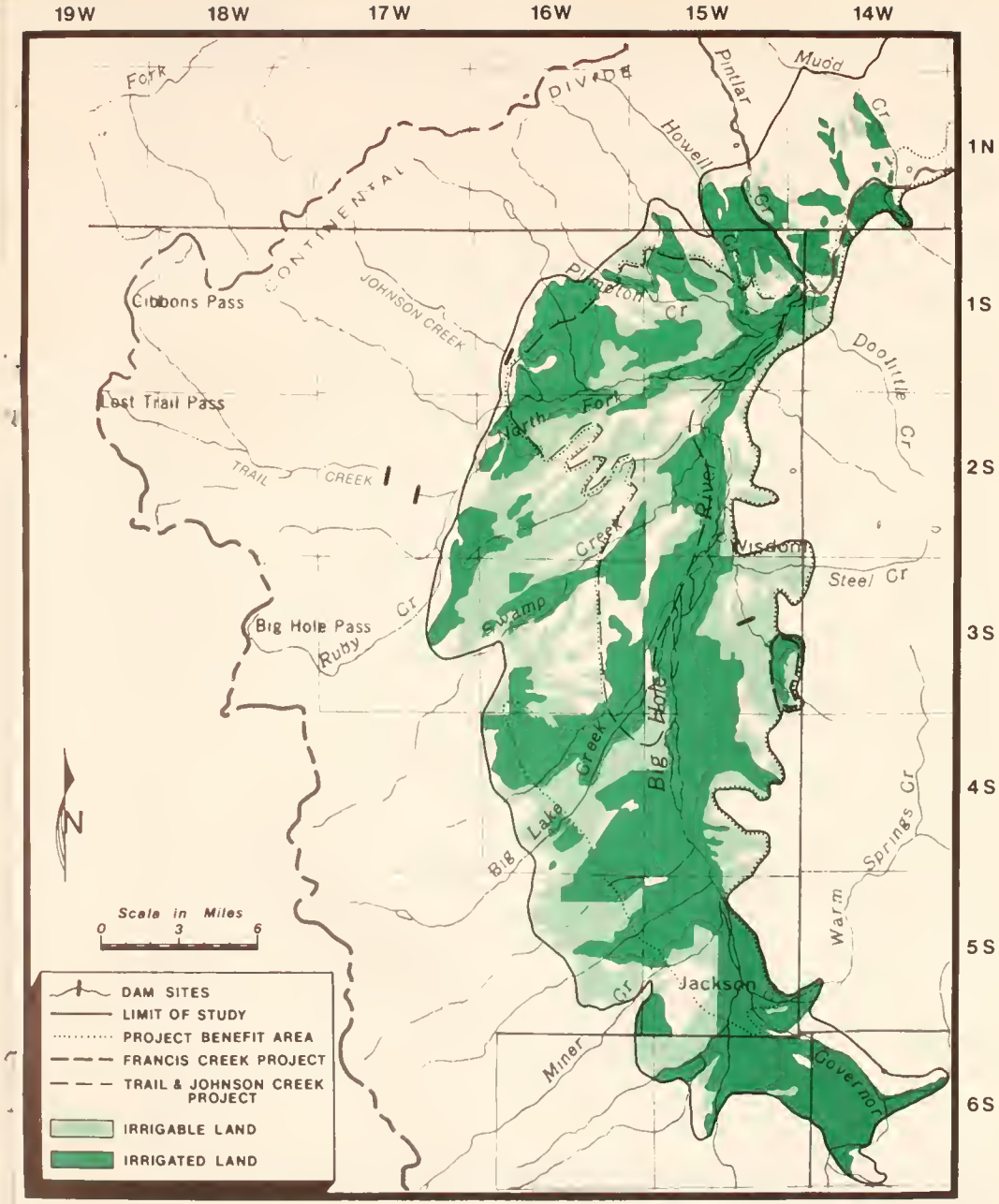


FIGURE 6 IRRIGATED (WITH A CURRENT PARTIAL WATER SUPPLY) AND IRRIGABLE LANDS IN THE UPPER BIG HOLE BASIN ; HEADWATERS TO MUDD CREEK. POTENTIAL AREAS FOR USE OF AN INCREASED WATER SUPPLY.

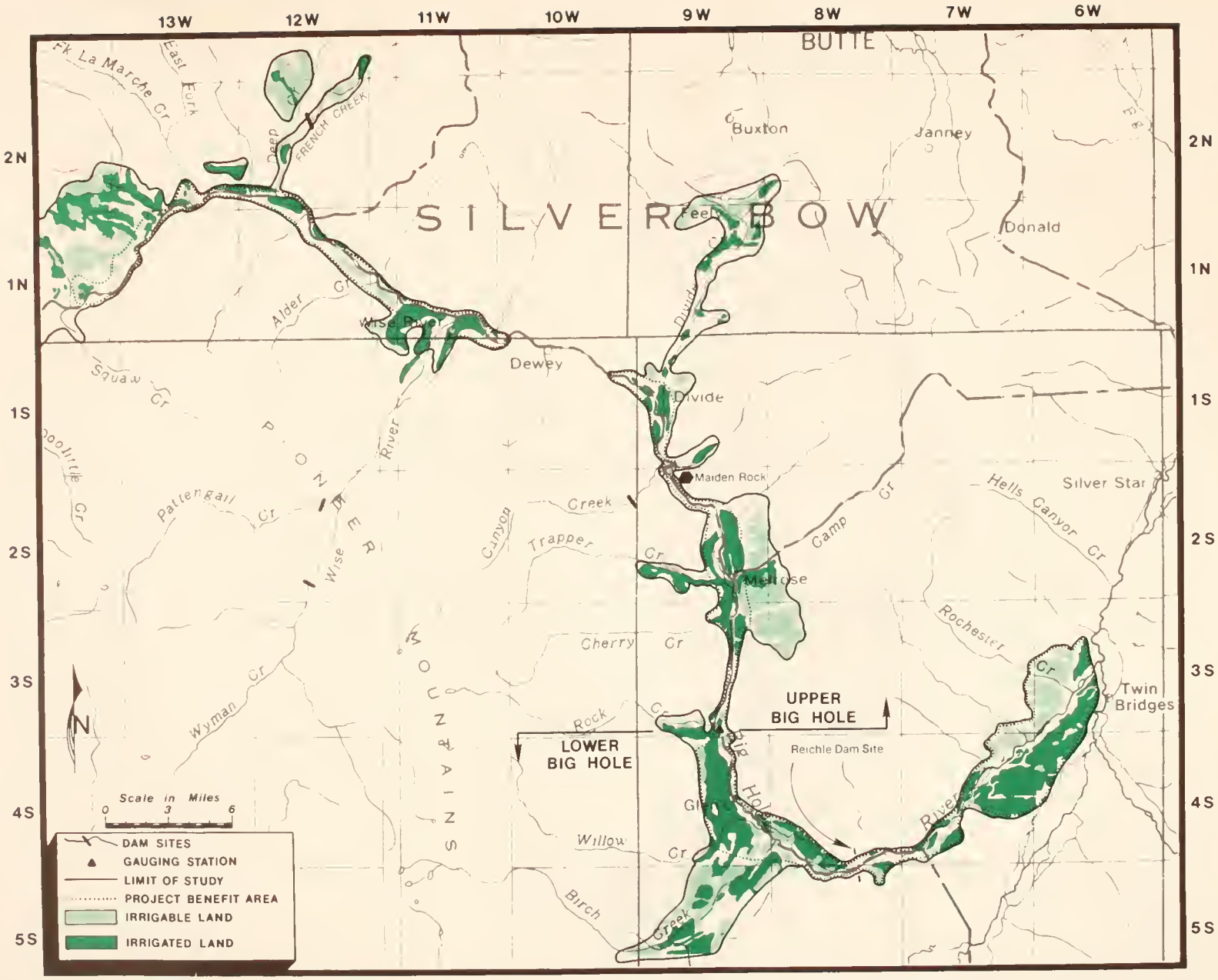


FIGURE 7 IRRIGATED AND IRRIGABLE LANDS IN THE BIG HOLE BASIN; POTENTIAL AREAS FOR USE OF AN INCREASED WATER SUPPLY.

The following sites have been considered in detail in this report (figure 8):

1. Pattengail Creek; Sec. 10, T. 2 S., R. 12 W.

This site is called the "Old Pattengail Creek Site"; a Montana Power Company dam was built here in 1901. Some years later Montana Power abandoned the dam, making a V-shaped cut in its center. Farmers who wanted to use the dam to store irrigation water filled in the cut. The structure was unstable and failed during spring runoff in 1927.

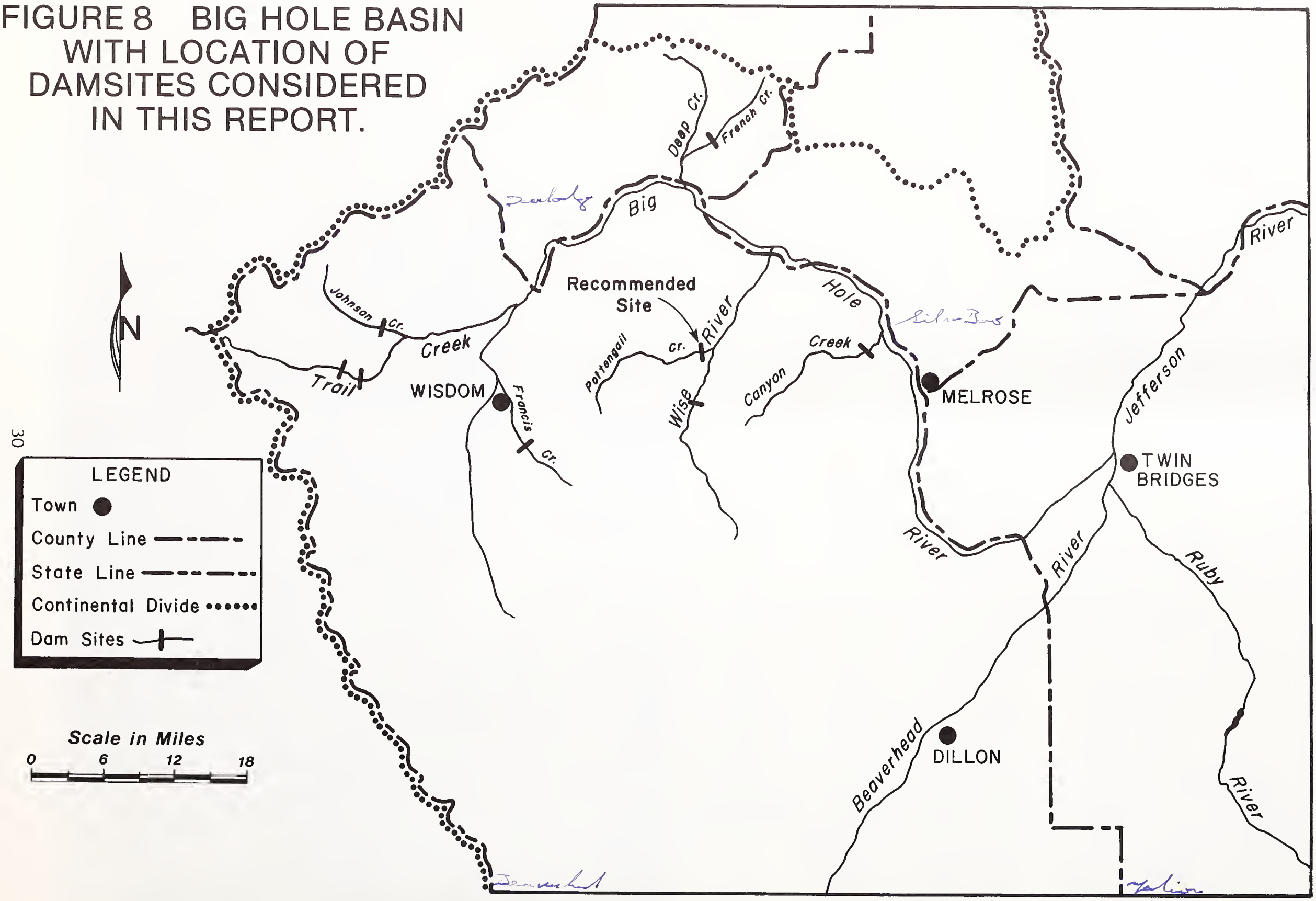
Earlier investigations of the site raised the possibility that the right embankment might consist of pervious rock talus as much as 150 feet thick. A recent geologic field investigation confirmed the presence of talus, but also found that glacial till underlies the talus from one bedrock wall to the other. Field observations suggest that the glacial till is impervious and is good for abutment and reservoir material. The pervious rock talus would not complicate design or add substantially to construction costs. Relative to other sites, development costs would be reasonable.

Because the maximum storage capacity of 12,425 acre-feet at this site is greatly exceeded by the average annual water supply of 35,126 acre-feet, there would be excess water in most years. The firm annual yield (the amount that would be available in all years) would be 10,140 acre-feet, an amount sufficient to irrigate 4,352 acres and add 170 cfs for one month to instream flows (or any distribution thereof). That firm annual yield would provide 73% of the amount needed for a full irrigation supply and a maintenance-level aquatic habitat in an average year and 26% in a dry year. These shortages occur in August and September and total 13,964 acre-feet, or 234 cfs in an average year. The figures include provision of minimum flows in Pattengail Creek in all years. The further downstream the water was sold for irrigation, the greater would be the instream benefits. Stored water would probably be released in August and September to best reduce instream shortages and provide additional water for irrigation.

The cost per acre-foot of water, including total annual project costs for repayment, operation, and maintenance is $36 in 1980 dollars. That estimate includes construction of two spillways. One would be a concrete spillway large enough to handle twice the peak discharge of a 100-year flood, and would handle most floods. The second spillway would be an emergency earth channel large enough to handle the largest flood this drainage basin could provide. The earth-lined spillway would permit controlled discharge of a maximum flood, but would be severely eroded in the process. The cost estimate does not include repairs to the earth-lined spillway after a flood.

Pattengail Creek site.

FIGURE 8 BIG HOLE BASIN WITH LOCATION OF DAMSITES CONSIDERED IN THIS REPORT.



The upper 2.4 km (1.5 mi.) of the reservoir pool was under study by the U.S.D.A. for wilderness potential as directed by the Montana Wilderness Study Act of 1977. It has not been recommended for wilderness designation by the U.S. Forest Service as reported in the Mt. Henry, Taylor-Hilgard, and West Pioneer Study Report (U.S.D.A.1980). This recommendation will now require Presidential and Congressional action. If this area were to be designated wilderness, an allowance would have to be made for the dam pool. The other 1.2 km (.75 mi) of reservoir and the dam site are on multiple-use national forest land.

A dam on Pattengail Creek would flood moose habitat for which compensation must be considered, but serious opposition by wildlife or environmental groups is not anticipated.

DNRC recommends that a dam be built at the Pattengail site. Because stored water from a reservoir on Pattengail Creek could be released from mid-July to September, the project could reduce dewatering in the Wise River and Big Hole and provide water for irrigation in the Wise River valley and the lower Big Hole and Jefferson basins. The stored water would relieve 73% of the total shortage in an average year and 26% in a dry year (the driest year of ten).

2. Wise River; Sec. 27, T. 2 S., R. 12 W.

The geology of the site, at a natural constriction in the valley floor, is good for dam construction. There are generous deposits of fill material in the area upstream from the site that would reduce construction costs. The maximum storage capacity with a single embankment is 216,270 acre-feet. The storage capacity could be increased to 313,758 acre-feet by adding two supplemental embankments on the left abutment of the damsite. The watershed would supply an average of 57,673 acre-feet per year. It is possible to build a dam that would hold more than a year's supply and then carry water over for dry years.

The effect of this reservoir on the basin's annual water supply is shown on table 12. Table 12 also shows the minimum number of irrigated acres that would get a firm water supply in the driest years from a reservoir at this site, and lists the cost per acre-foot for the water supply.

All the data on table 12 assume that instream flow requirements for minimum flows in the Wise River are met, and the remaining water is allocated to irrigation or instream use for comparison purposes.

The costs include road and ranger station relocation, dam construction and embankment costs, and engineering, construction, and inspection costs.

Water from a reservoir at this site could be used for instream and irrigation in the lower basin but would not help the upper basin's irrigation needs.

Portions of the east bank of the dam pool on any of the reservoir sizes over 50,000 acre-feet would be in the East Pioneer Wilderness Study Area. This area was considered under the RARE II Wilderness Designation procedure, and recommended by the study team as a wilderness area. If it were to be designated as wilderness, a minor boundary adjustment would likely resolve any conflict.

Dewatering in the Wise River, August 1980.

There would be a great deal of environmental opposition to a proposal for a dam at this site because much of the 1,100 acres to be inundated is critical moose habitat. In winter, moose migrate freely up and down this drainage.

Water from this site would relieve shortages in the Wise River itself as well as in the lower basin. There would be little instream seepage loss downstream from this site because of the geological formations.

The cost data developed for the Wise River site are based on the use of surcharge to contain the probable maximum flood rather than on construction of a more costly spillway to pass this flood.

Flooding this area would create significant environmental opposition. This site is not recommended for dam construction because of the importance of the moose habitat and because of the site's aesthetic values.

3. French Creek; Sec. 16, T. 2 N., R. 12 W.

The geology at the proposed French Creek site is suitable for tributary storage and does not present unusual geologic or engineering problems. There is a major thrust fault in the reservoir area, but it would not prevent locating a dam at this site.

There is little potential for seepage loss at this site. It is possible that the limited supply of nearby materials for earthfill construction might require special cutoffs or rockfill design, which would increase the estimated costs.

The French Creek site has a maximum storage capacity of 28,855 acre-feet. The firm annual yield and the percentage of yearly supply that would be regulated for irrigation, instream, or flood control during the projected ten-year critical period of lowest streamflow are shown on table 13 for different reservoir capacities.

According to a methodology developed by the U.S. Corps of Engineers and presently used by the State of Montana, the estimated peak discharge for a probable maximum flood in this drainage is 96,000 cfs. Private cabins, a state highway, and ranch buildings are in the potential flood path from a reservoir at this site; therefore, all spillway designs and cost estimates must be for a high-hazard dam that could pass the probable maximum flood. If detailed flood-routing studies for this site show that spillway designs can be based on less hazardous flood potential, then project costs would be reduced accordingly.

Another consideration for dam construction at French Creek is that it is on the Mt. Haggin Ranch owned by the Department of Fish, Wildlife and Parks. The purchase of this ranch was made with grant money from the Nature Conservancy and the purchase agreement stipulates that the land be managed to benefit fish, wildlife, and recreation and provide range for game. If management changes are made, the benefits to any of these management concerns must at least exceed the losses to the others.

Some of the creeks that would provide the water supply to a dam at this site have elevated arsenic levels. Storage of this water and its release during periods of low flow may cause water quality problems. If a dam is ever proposed for this site, this arsenic problem should be investigated.

DNRC does not recommend construction at this site because it would serve basically the same area as a dam at Pattengail Creek and the Pattengail site would provide twice as much water at half the cost per acre-foot.

French Creek site.

4. Johnson Creek; Sec. 30, T. 1 S., R. 16 W.

Geologically, this is a good site for an earthfill dam. Construction materials are available nearby. A dam would develop about 150,000 acre-feet of storage capacity with a dam 180 feet high. The watershed draining to this site is 38 square miles and yields a calculated average annual water supply of 28,363 acre-feet.

The percentage of the long-term average annual water supply that would be regulated by a multipurpose reservoir during the projected ten-year critical period of lowest streamflows is shown on table 14 for different reservoir capacities. The firm annual yield would be the amount available in the driest of years and if used for irrigation would serve the number of acres shown on table 14.

The Johnson Creek site could serve 26,261 acres of currently irrigated lands that at present suffer water shortages in most years. An additional 17,805 acres of land that are suitable for irrigation, but are not now irrigated, could be served from a dam at this site. The lands that could be served from this site are essentially the same lands that could be served from the Trail Creek sites.

The estimated peak flood discharge is 69,000 cfs with an estimated total volume of 20,000 acre-feet. Due to the amount of runoff potential in the area and resultant hazards, construction costs have to be based on the probable maximum flood. Spillway construction costs could be substantially reduced by building excess capacity to store surplus water instead of building an emergency spillway. Costs might be further reduced if detailed flood routing studies could reduce the dam's hazard classification.

DNRC does not recommend a dam at this site because, even though irrigators could use all the water, the cost of water is too high to be paid by agricultural uses alone; there are no major instream shortages in the upper basin so instream benefits could not be used to help pay for the water.

5. and 6. Trail Creek, two sites: Thin Man, Sec. 15, T. 2 S., R. 15 W., and Fat Man, Sec. 14, T. 2 S., R. 18 W.

Two sites were studied on Trail Creek. The upstream site is called Thin Man, and the downstream site is called Fat Man. Both Trail Creek sites are on granitic bedrock, and the geology is suitable for dam construction. The probable lack of impervious earthfill in the area might limit dam design to a rockfill structure or could require special design of an earthfill embankment. These requirements would increase costs substantially.

The average annual water supply is 37,545 acre-feet. Either site could store approximately 135,900 acre-feet with a dam 176 feet high.

The percentage of the long-term average annual water supply that would be regulated for irrigation and maintenance-level fish habitat during the projected ten-year critical period of lowest streamflows is shown on table 15 for different reservoir capacities. The information in the table decribes the Fat Man site but also applies to the Thin Man site. The firm annual yield is the amount of water that would be available in the driest of years and if used for irrigation would serve the number of acres shown on table 15.

Table 14: Regulation, firm annual yield, irrigated acreage, and costs per acre-foot for reservoir capacities at the Johnson Creek site.

RESERVOIR CAPACITY (ACRE-FEET)	% OF AVERAGE ANNUAL SUPPLY REGULATED	ACRE-FEET REGULATED	FIRM ANNUAL YIELD (ACRE-FEET)	MAXIMUM IRRIGATED ACRES	TOTAL COST OF DAM	COST PER ACRE-FOOT (1980 DOLLARS)
5,000	85.2	24,265	8,185	3,513	6,131,000	58
10,000	95.0	26,945	8,185	3,513	6,889,000	65
15,000	95.6	27,115	8,185	3,513	7,494,000	69
20,000	95.6	27,115	8,185	3,513	8,098,000	76
30,000	95.6	27,115	12,957	5,561	9,303,000	128
40,000	95.6	27,115	12,957	5,561	10,508,000	143
60,000	95.6	27,115	12,957	5,561	12,187,000	167
80,000	95.6	27,115	24,626	10,569	13,817,000	100
100,000	95.6	27,115	25,199	10,815	15,472,000	109

Table 15: Regulation, firm annual yield, irrigated acreage, and costs per acre-foot for reservoir capacities at the Fat Man site.

RESERVOIR CAPACITY (ACRE-FEET)	% OF AVERAGE ANNUAL SUPPLY REGULATED	ACRE-FEET REGULATED	FIRM ANNUAL YIELD (ACRE-FEET)	MAXIMUM IRRIGATED ACRES	TOTAL COST OF DAM	COST PER ACRE-FOOT (1980 DOLLARS)
5,000	82.1	30,824	10,380	4,455	11,798,000	81
6,000	84.0	31,538	10,380	4,455	11,901,000	81
10,000	91.5	34,354	10,380	4,455	12,315,000	82
15,000	95.6	35,893	10,380	4,455	12,969,000	90
20,000	95.6	35,893	10,380	4,455	13,623,000	97
40,000	95.6	35,893	17,156	7,363	16,337,000	72
60,000	95.6	35,893	17,156	7,363	18,286,000	80
80,000	95.6	35,893	17,156	7,363	19,741,000	85
100,000	95.6	35,893	26,706	11,462	21,084,000	59

A dam at either of these sites could serve 26,261 acres now irrigated with short water supply and 17,805 acres of potentially irrigable lands not now irrigated.

It is tentatively assumed that a dam on either of the Trail Creek sites would have to meet safety criteria for a high-hazard dam.

It would be far cheaper to build excess capacity to contain a probable maximum flood than to build an emergency spillway.

Approximately 5.3 miles of state highway would have to be relocated, at an estimated cost of $1 million per mile. Relocating the road would be relatively expensive because drilling and blasting would be required in most of the road cuts; those expenses have been considered in the cost estimates.

DNRC does not recommend building a dam at either of these sites because the cost of water is too high to be paid by agricultural uses alone. Because there would be no major instream benefits, no instream interests would help pay for the water.

7. Canyon Creek; E. ½, Sec. 12, T. 2 S., R. 10 W.

This site was evaluated by DNRC in 1978 and 1979.

This site can provide an estimated average annual water supply of 23,040 acre-feet from a 45-square-mile watershed. A dam 169 feet high and 2,000 feet long would develop a reservoir capacity of about 15,000 acre-feet.

While it is possible that a reservoir might be economically developed, preliminary geologic investigations indicate the potential for reservoir seepage losses rule out further consideration of this site.

8. Francis Creek; Sec. 15, T. 2 S., R. 15 W.

The capacity of a reservoir at this site would be 9,670 acre-feet, most of which would be diverted from the Big Hole River. Because the town of Wisdom might be in a flood path if the dam were to fail, the dam would be classified as high-hazard, requiring a spillway constructed to high-hazard standards, increasing water costs considerably.

There is a high potential for seepage loss under a dam at this site because the Tertiary sediments in the reservoir area contain considerable amounts of sand and gravel. The site is unsuitable for dam construction and has been dropped from further consideration.

Current Cost Considerations

The cost estimates presented above are significantly higher than those presented in DNRC (1978) and Brown et al. (1979) for these reasons:

1. Spillway costs are higher in these estimates because spillway criteria are for probable maximum floods. Use of these criteria is presently required by the U.S. Corps of Engineers National Dam Safety Program.
2. These cost estimates include interest charged over forty years on construction loans.
3. In these estimates, project life and the repayment period for 1980 capital costs is forty years at a 6 7/8% discount rate.
4. All project costs include a 25% contingency for engineering design specifications, engineering site investigations, materials administration, construction engineering, and construction inspection.

IV. CONCLUSIONS

1. There are existing water shortages for agricultural use in the upper basin of the Big Hole and for agricultural and instream use in the lower basin. There are no current shortages in the Jefferson River basin from its confluence with the Big Hole to Whitehall. The existing shortages in the Big Hole, for agriculture and instream uses in an average year, total 113,644 acre-feet to provide a maintenance-level fish habitat and 308,708 acre-feet for an ideal habitat.

2. Water storage on the mainstem is not recommended as a solution to Big Hole basin water shortages.

3. Geologically, much of the upper basin looks favorable for ground-water development, but studies have not been made to determine how much ground water could be tapped. The existing electrical power distribution system in the upper basin is not adequate to supply electricity for development of ground-water wells, and expanding this system or developing alternative energy sources would be expensive. Even assuming electricity is available, current cost estimates for use of ground water are prohibitive ($55/acre-foot).

4. The ground-water system in the Big Hole is saturated and ground water moves very slowly. For this reason, most of the excess irrigation water applied to the land returns, rather quickly, overland to the water source. Therefore, water conservation through improved irrigation efficiency would have little effect on water shortages.

5. If certain laws were changed, it would be possible to rent agricultural water rights to alleviate instream shortages in times of need.

6. If dams were built at all tributary storage sites considered in this report, a total of 173,000 acre-feet of additional water could be provided in an average year. No single site will solve the water shortage problem in the Big Hole, but construction of a single, carefully operated dam could significantly reduce the water shortage problem in the Big Hole.

7. There are enough irrigable but not currently irrigated acres in the Big Hole and Jefferson basins to use all water that could be provided by tributary storage. There is enough need for supplemental water in the upper basin to use all the water that could be provided by tributary storage.

8. Delivery of stored water to those who purchase it would require some type of monitoring and regulation program.

9. Natural seepage losses from the Big Hole will not significantly hinder water delivery from tributary storage sites to potential users.

10. The eight tributary storage sites studied are on Francis Creek, Canyon Creek, Trail Creek, Johnson Creek, French Creek, Wise River, and Pattengail Creek. The sites on Francis Creek and Canyon Creek are unsuitable for dam construction. Sites at Wise River, Trail Creek, Johnson Creek, French Creek, and Pattengail Creek are suitable for dam construction.

11. Trail and Johnson creeks are located in the upper basin where there are irrigation shortages but no instream shortages. Trail Creek is the larger and more economical of the two. Because the water from these sites would be too expensive for irrigators alone to afford, the only financially feasible sites are those that serve the lower basin where instream interests can share the costs with agriculture: French Creek, Wise River, and Pattengail Creek.

12. The site on Pattengail Creek is twice as large as the one on French Creek (10,000 acre-foot firm annual yield versus 5,000) and the water is about one-half the cost ($36/acre-foot at Pattengail versus $60/acre-foot at French Creek); so, French Creek has been eliminated. The cost of water at the Pattengail site is approximately the same as at Wise River ($36/acre-foot for Pattengail and $30 for Wise River), but a proposal to build a dam at the Wise River site would cause insurmountable environmental concerns because the reservoir would flood critical moose habitat and because the area has great aesthetic value. Therefore, the Wise River site was dropped.

13. DNRC recommends that a dam be built at the Pattengail site. Because stored water from a Pattengail reservoir could be released from mid-July to September, the project could improve the dewatering problem in the Wise River and Big Hole, as well as provide water for irrigation in the Wise River valley, the lower Big Hole basin, and the Jefferson basin. For example, the firm annual yield would be sufficient to irrigate 4,352 acres and add 170 cfs (10,140 acre-feet) for one month to instream flows. In an average year, this would be sufficient to eliminate 73% of the shortages for maintenance-level habitat in the Wise River and lower Big Hole. In a dry year (the driest year in ten), stored water from Pattengail would relieve 26% of the total shortage.

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APPENDIX

RESULTS OF DNRC SURVEY OF IRRIGATORS IN THE BIG HOLE BASIN

DNRC conducted a survey of 66 landowners who are near enough to the Big Hole River that they could irrigate from the mainstem. Theoretically, they could use water provided to the mainstem by tributary storage. Following are the questions in the survey and a summary of responses.

1. *Approximately how many acres do you (fill in blank space in acres):*

   a. *Cultivate (unirrigated)*_____

   b. *Irrigate (total)*_____
   *Full irrigation*_____
   *Partial irrigation*_____

   c. *Number of acres that you consider irrigable but that you are not currently irrigating*_____.

		Lower basin	Upper basin
Valid responses		30	25
a.	Cultivated acres	900	7,675
b.	Total irrigated	13,363	20,069
	Full irrigation	11,460	18,965
	Partial irrigation	1,903	1,138
c.	Irrigable	13,906	15,595

2. *Major products of your operation (e.g. alfalfa, barley, cattle, etc.) please list in order of importance (fill in blank spaces):*

   *10 years ago*_____

   *5 years ago*_____

   *Now*_____

   *Yield per acre*_____

   *Expected in foreseeable future*_____

	Lower basin	Upper basin
Valid responses	29	24
Products 10 years ago* (average per ranch)	332 animal units	352 animal units
Products 5 years ago* (average per ranch)	360 animal units	363 animal units
Products now* (average per ranch)	356 animal units	385 animal units
Yield per acre (hay)	2.2 ton	2.0 ton

*Some respondents answered these questions in terms of hay or barley but since the great majority answered in terms of animal units, only these were compiled.

3. *What is your present method of irrigation? (fill in blank spaces)*

		Percent of total irrigation
a.	*Uncontrolled flooding*	_____
b.	*Controlled flood (i.e. using border dike, contour furrow, gated pipe etc.)*	_____
c.	*Side roll*	_____
d.	*Center pivot*	_____
e.	*Big gun*	_____
f.	*Other* _____ *(please specify)*	_____

	Lower basin	**Upper basin**
Valid responses	30	24
	% of total irrigation	
a. Uncontrolled flooding	9%	1%
b. Controlled flooding	76%	88%
c, d and e. Side roll, center pivot, or big gun	15%	11%

4. *Approximately how much water do you use per acre?*

_____ *acre-feet or miner's inches. (Please circle proper unit of measurement.)*

	Lower basin	**Upper basin**
Valid responses	24	28
Water per acre	.8 acre-foot per irrigation	1.0 acre-foot per irrigation

5. *What is your present water source? (please name stream, river, or ditch company).* _____

Lower basin: Of the 30 individuals who gave valid responses, all respondents indicated that they get water from the Big Hole River or from ditches fed by the Big Hole River.

Upper basin: Of the 23 individuals who gave valid responses as to the source of their water, 15 respondents get water directly from the Big Hole River and 4 get water from the Wise River. The rest get water from ditches and tributary streams. This is not representative of irrigation as a whole in the upper Big Hole because only the irrigators along the mainstem were questioned.

6. *What is total volume of present diversion?*

*(Specify unit of measurement)*_____

_____ *priority date*

_____ *is it a provisional permit? If so, what are the provisions?*

This question did not produce replies that were useful for comparison.

7. *How many times during the season do you irrigate? If possible, estimate dates.*

	Lower basin	Upper basin
Valid Responses	29	18
Total water per acre per irrigation (from question 4)	.8 AF	1.0 AF
Average number of irrigations	5	4
Average length of irrigation season	153 days	135 days
Earliest date beginning irrigation	April 1	April 1
Latest date beginning irrigation	May 15	June 1
Average date beginning irrigation	May 2	May 11
Earliest date ending irrigation	July 13	July 1
Latest date ending irrigation	October 15	September 30
Average date ending irrigation	September 25	August 15

8. *If you have a water shortage, please describe the extent of it. Approximately, during what times does it occur?*

Lower basin: Of the 29 individuals who gave valid responses as to when they had water shortages, 22 indicated that there are water shortages in August. Fifteen respondents indicated water shortages in July and 13 indicated water shortages in September. Seven respondents indicated no water shortages.

Upper basin: Of the 25 individuals who gave valid responses as to when they had water shortages, 21 indicated water shortages in August, 14 indicated water shortages in July, 14 indicated water shortages in September and 3 indicated water shortages in June. One respondent indicated no water shortages.

9. *Presently, what are you paying for your water?*

free _____

$.01 - 1.99 _____

$2 - 3.99 _____

$4 - 5.99 _____

$6 - 7.99 _____

$8 - 9.99 _____

More than $10 (Note how much) _____

What percent of your water is at this cost? _____

What is the cost of the remaining water? _____

Lower basin: All 30 valid responses as to the cost of their water indicated that the respondents' water costs between $0.01 and $1.99 per acre-foot. One respondent, however, indicated that he pays up to $3.99 per acre-foot on some land and another indicated that he pays up to $9.99 per acre-foot on some land.

Upper basin: All 25 valid responses as to the cost of their water indicted that the respondents' water costs between $0.01 and $1.99 per acre-foot. One respondent indicated, however, that he pays up to $3.99 per acre-foot on some land and another indicated that he pays up to $5.99 per acre-foot on some land.

10. *If you could make more profit, would you convert acreage from dryland to irrigated?* *yes* *or* *no* *(please circle appropriate answer) If not, why: (check appropriate blank)*

a. *too big an initial investment?* _____

b. *not enough profit?* _____

c. *too much manpower involved?* _____

d. *simply would choose not to?* _____

e. *inadequate water supply?* _____

f. *other (please specify)* _____

Lower basin: All but one of the 30 valid responses indicated that the respondents would either increase irrigation or already have all land under irrigation. The one who replied that he would not increase irrigation indicated that it would require too big an initial investment and too much manpower, and not produce enough profit.

Upper basin: All but two of the 24 valid responses indicated that the respondents would either increase irrigation or already have all land under irrigation. Of those who indicated that they would not convert unirrigated to irrigated land, one said his land is too rocky, and the other said his land is too difficult to flood.

11. *How much land did you irrigate? (fill in blanks)*

3 years ago _____

5 years ago _____

10 years ago _____

20 years ago _____

	Lower basin	**Upper basin**
Valid responses	24	24
3 years ago	13,000 acres	20,000 acres
5 years ago	12,000	19,500
10 years ago	11,000	17,500
20 years ago	9,500	16,500

12. *If you have increased your irrigation, what was the reason for the increase? (circle appropriate answer(s))*

a. *new funds available*

b. *new water available*

c. *change of management*

d. *change of management practices*

e. *new technology available*

f. *bought/leased new land*

g. *more profitable*

h. *more dependable yields*

i. *other* _____ *(please specify)*

Lower basin: Seventeen individuals gave valid responses as to the reason for having increased their irrigation. Fourteen individuals indicted "more profitable," 13 indicated "more dependable yields," 4 indicated

"new technology available," 3 indicated "change of management practices," 3 indicated "bought/leased new land," and 2 gave other reasons.

Upper basin: Twenty individuals gave valid responses as to the reason for having increased their irrigation. Seventeen individuals indicated "more profitable," 13 indicated "more dependable yields," 1 indicated "new funds available," 1 indicated "change of management," 1 indicated "change of management practices," 1 indicated "bought/leased new land," and 3 gave other reasons.

13. If you have decreased your irrigation, what was the reason for the decrease? (circle appropriate answer(s) and fill in blanks if necessary)

a. *not profitable—land could be put to use more profitably by* _____

b. *lack of sufficient water*

c. *major repair needed for delivery system*

d. *change of management*

e. *sold or dropped lease on some land*

f. *other*_____ *(please specify)*

Lower basin: Only one individual gave a valid response as to the reason for having decreased irrigation and that reason was "sold or dropped some land."

Upper basin: Only two individuals gave valid responses as to the reason for having decreased irrigation. Those reasons were "major repair needed for delivery system" and "highway construction."

None cited water shortages as a reason for decreased irrigation.

14. Do you plan to increase your irrigated acreage in the foreseeable future? Yes or No (circle correct answer)

a. *If so, how many acres?* _____

b. *If so, why?*
1. *more profitable than non-irrigated land*
2. *new loan money available for irrigation development. If so, source?*
3. *new management*
4. *other (please specify)* _____

Lower basin: Nineteen individuals indicated that they planned to increase their irrigation operation. Eighteen indicated "more profitable than nonirrigated land" and 1 indicated "new management" as the reason for the planned increase. The total planned increase amounted to 3,493 acres.

Upper basin: Nineteen individuals indicated that they planned to increase their irrigation operation. Nineteen indicated "more profitable than nonirrigated land" as the reason. One respondent indicated that due to an increase in past due permits that he needed more hay in addition to "more profitable than nonirrigated land." The total planned increase amounted to 11,520 acres.

15. What would be the water source for increased irrigation?

*Surface*_____ *Name of source*_____
Groundwater _____

Lower basin: Of the 19 valid responses regarding the source of water for additional irrigation, all indicated that the Big Hole River would be used as a major source.

Upper basin: Of the 25 valid responses regarding the source of water for additional irrigation, 11 indicated that the Big Hole River would be used as a major source, 3 indicated the Wise River and the rest indicated smaller tributary streams.

16. *If you increase your irrigation, what method do you plan to use?*

a. *flood*

b. *sideroll*

c. *center pivot*

d. *big gun*

Lower basin: Twenty-one individuals gave valid responses as to the methods of irrigation they would use on additional acreage. Seven indicated that they would use flood irrigation and 18 would use some kind of sprinkler irrigation.

Upper basin: Twenty-five individuals gave valid responses as to the methods they would use to irrigate additional acreage. Seven indicated that they would use flood irrigation and 20 would use some kind of sprinkler irrigation.

17. *What method of irrigation would you use if water were: (check appropriate boxes)*

	uncontrolled flood	*controlled flood*	*sideroll*	*center pivot*	*big gun*
free					
$.01 - 1.99/AF					
$2 - 4.99/AF					
$5 - 7.99/AF					
$8 - 10.99/AF					
$11 - 13.99/AF					
$14 - 17.99/AF					
$18 - 20.00/AF					

This question did not provide results that were useful for comparison.

18. *What other criteria (other than cost of water) do you foresee using to change methods of irrigation?*

a. *water availability*

b. *probability of increased crop production*

c. *available funds for irrigation equipment*

d. *none*

e. *other (please specify)* _____

Lower basin: Twenty-seven individuals gave valid responses regarding criteria other than the cost of water that they foresaw using to change methods of irrigation. "Water availability" was given 23 times, "probability of increased crop production" was given 10 times, "available funds for irrigation equipment" was given 5 times, and "labor" was given once. One respondent indicated that he would not use any criterion other than the cost of water.

Upper basin: Twenty-four individuals gave valid responses regarding criteria other than the cost of water that they foresaw using to change methods of irrigation. "Water availability" was given 20 times, and "available funds for irrigation equipment" was given 8 times. One respondent indicated that he would not use criteria other than the cost of water.

19. *How far from the source do you deliver water? (circle correct answer)*

a. *less than ½ mile*

b. *½ to 1 mile*

c. *1 - 2 miles*

d. *2 - 3 miles*

e. *More than 3 miles (how many?)*

	Lower basin	Upper basin
Valid responses	30	24
Distance water delivered:		
a. less than ½ mile	13%	8%
b. ½ to 1 mile	23%	21%
c. 1 to 2 miles	20%	29%
d. 2 to 3 miles	27%	25%
e. more than 3 miles	30%	17%

The greater distance for water delivery in the lower basin is due to the fact that most irrigators use large ditches which serve many irrigators rather than private systems.

20. *What kind of delivery system do you have:*

a. *unlined ditch*

b. *lined ditch*

c. *pipe*

d. *other (please specify)* _____

Lower basin: Of the 30 individuals who gave valid responses regarding delivery systems, all 30 indicated that they used unlined ditches. Eight responses also indicated that pipe was also used in delivering irrigation water.

Upper basin: Of the 25 individuals who gave valid responses regarding delivery systems, 24 indicated that they use unlined ditches. Two of these individuals also indicated that they use pipe in addition to lined ditches. One individual indicated that he used line ditches.

21. *What type of diversion do you have?*

a. *pump*

b. *dike*

c. *headgate*

d. *other (please specify)* _____

Lower basin: Of the 30 individuals who gave valid responses regarding their means of diversion, all 30 indicated that they use headgates. Seven also use pumps and 12 also use dikes.

Upper basin: Of the 25 individuals who gave valid responses regarding their means of diversion, 24 indicated that they use headgates, 5 use pumps, and 9 use dikes.

22. Could you use your present delivery system to deliver more water to irrigate additional acres? (Yes or No) If so, how much? (Specify units used, i.e., acre-feet, miners inches, or acres which could be irrigated) _____

Lower basin: Of the 23 individuals who gave valid responses regarding whether their delivery systems could deliver more water, 17 replied yes and 6 replied no.

Upper basin: Of the 25 individuals who gave valid responses regarding whether their delivery systems could deliver more water, 18 replied yes and 10 replied no.

23. If future water would be made available through storage, would you irrigate additional acres? If so, how many if the water were: (fill in blank)

	# of acres	amount of water (specify units)
free	_____	_____
$.01 - 1.99/AF	_____	_____
$2 - 4.99/AF	_____	_____
$5 - 7.99/AF	_____	_____
$8 - 10.99/AF	_____	_____
$11 - 13.99/AF	_____	_____
$14 - 17.99/AF	_____	_____
$18 - 20.00/AF	_____	_____

Lower basin: Of the 25 individuals who gave valid responses to whether they would be willing to buy water to irrigate new land, 6 indicated that they would not. Of the 18 individuals indicating that they would be willing to purchase stored water for new irrigation, 1 indicated that he would be willing to pay up to $1.99 per acre-foot, 16 indicated they would pay up to $4.99 per acre-foot, and 1 indicated that he would be willing to pay up to $10.99 per acre-foot. In all, the respondents indicated that they would put a total of 4,608 acres under new irrigation.

Upper basin: Of the 24 individuals who gave valid responses as to whether they would be willing to buy water to irrigate new land, 5 said they would not. Of the 19 indicating that they would be willing to buy water for new irrigation, 2 indicated that they would be willing to pay up to $1.99 per acre-foot, 16 indicated that they would be willing to pay up to $4.99 per acre-foot. In all, the respondents indicated that they would put a total of 7,415 acres under new irrigation.

24. Would you convert from partial to full irrigation? (Fill in blanks, specify units) If so, how many if the water were:

	# of acres	amount of water (specify units)
free	_____	_____
$.01 - 1.99/AF	_____	_____
$2 - 4.99/AF	_____	_____
$5 - 7.99/AF	_____	_____
$8 - 10.99/AF	_____	_____
$11 - 13.99/AF	_____	_____
$14 - 17.99/AF	_____	_____
$18 - 20.00/AF	_____	_____

Why have you not made this conversion to date? (Check correct answer)

a. *inadequate water supply*

b. *not enough profit*

c. *other* _____

Lower basin: Of the 5 individuals who gave valid responses as to whether they would be willing to pay for water to convert partial irrigation to full irrigation, 1 replied that he would not. Of those indicating that they would be willing to pay for water for conversion to full irrigation, 2 indicated that they would be willing to pay up to $1.99 per acre-foot and 2 indicated that they would pay up to $4.99 per acre-foot. In all, the respondents indicted that they would convert a total of 1,286 acres to full irrigation.

Upper basin: Of the 11 individuals who gave valid responses as to whether they would be willing to pay for water to convert partial irrigation to full irrigation, 6 replied no. All 5 indicating a willingness to pay for water to convert to full irrigation indicated that they would pay up to $4.99 per acre-foot to do so. In all, the respondents indicted that they would convert a total of 4,525 acres to full irrigation.

25. Under what conditions and during what times of the irrigation season would you be interested in additional water for irrigation?

Lower basin: Of the 28 individuals who gave valid responses as to the conditions and times of the irrigation season they would be interested in additional water, 1 individual indicated that he would not be interested at all. Of those that would be interested, 1 indicated that he would buy irrigation water in June, 19 in July, 26 in August, 19 in September, and 1 in October.

Upper basin: Of the 24 individuals who gave valid responses as to the conditions and times of the irrigation season they would be interested in additional water, 2 indicated that they would be interested in May, 4 in June, 17 in July, 22 in August, and 16 in September.

26. Describe extent of current dewatering in the area of your diversion.

Lower basin: With regard to the extent of current dewatering, 7 individuals report dewatering in July, 10 in August, and 7 in September.

Upper basin: With regard to the current extent of dewatering, 2 report dewatering in July, 4 in August, and 4 in September.

27. Have you considered irrigating with groundwater? *Yes or No*

Would you consider use of groundwater if:

a. surface supplies were unreliable *Yes or No*

b. water cost more than:

(Please check appropriate blanks)

free	_____
$.01 - 1.99/AF	_____
$2 - 4.99/AF	_____
$5 - 7.99/AF	_____
$8 - 10.99/AF	_____
$11 - 13.99/AF	_____
$14 - 17.99/AF	_____
$18 - 20.00/AF	_____

Lower basin: Of the 28 individuals who gave valid responses as to whether they have considered irrigating with ground water, 6 replied yes and 22 replied no. Eight individuals indicated that they would consider ground water if surface water became unreliable but 10 indicated that they still would not consider ground water. One indicated he would consider ground water if surface water cost more than $1.99, 4 indicated the same if surface water cost more than $4.99, and 1 indicated the same if surface water cost more than $7.99.

Upper basin: Of the 22 individuals who gave valid responses as to whether they have considered irrigating with ground water, 3 replied yes and 22 replied no. Four individuals indicated that they would consider ground water if surface water became unreliable but 5 indicated that they still would not consider ground water. Two indicated they would consider ground water if surface water cost more than $4.99, and two indicated the same if surface water cost more than $7.99.

28. If purchasing shares in a water storage project were the only way to acquire more water for irrigation, would you do so? *Yes or No.*

Lower basin: Twenty-seven individuals gave valid responses to this question. Twenty-three replied yes and 4 replied no.

Upper basin: Twenty-five individuals gave valid responses to this question. Twenty-one replied yes and 4 replied no.

29. If you needed more irrigation water now, where would you get it?

Lower basin: Of the 25 individuals who gave valid responses as to where they would get water if they needed it now, 19 replied storage, 5 replied ground water, and 3 replied the Big Hole River.

Upper basin: Of the 21 individuals who gave valid responses as to where they would get water if they needed it now, 21 replied storage, 4 replied the Big Hole River, 1 replied ground water, and 1 replied Trail Creek.

30. What is your opinion of the water availability situation in your area, and how do you feel about the possibility of off-stream storage?

This question did not provide results that were useful for comparison.

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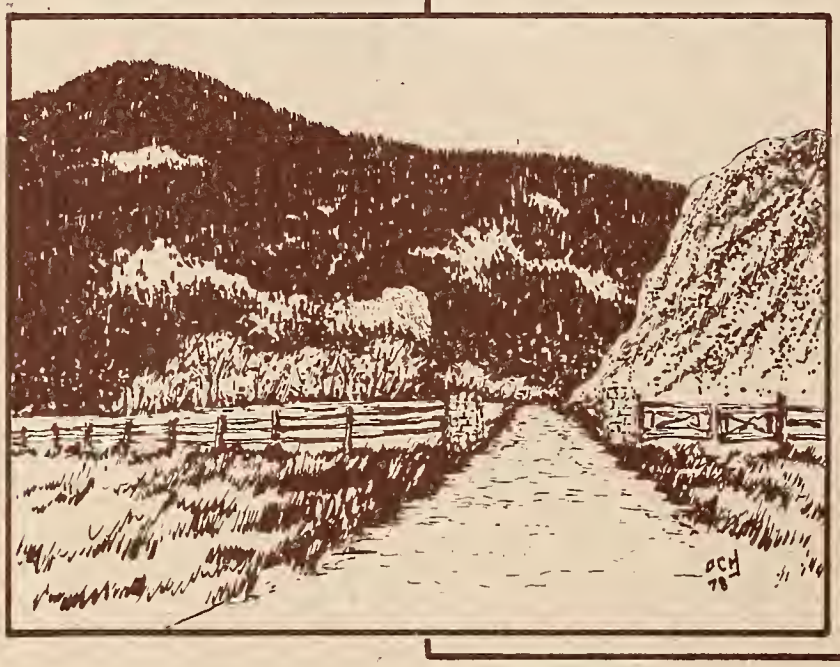

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